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Vol. I

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MARTIN
MARIETTA
CORPORATION
DENVER DIVISION

VOYAGER
CAPSULE

PRELIMINARY DESIGN (Phase B)

Contract Number 952001 FINAL REPORT

VOLUME I SUMMARY

AUGUST 31, 1967

A. J. Kullas
Voyager Program Director

FOREWORD

This document is submitted in accordance with paragraph (a)(9) of Article 1, Statement of Work, to California Institute of Technology Contract No. 952001, which is a subcontract under NASA Contract NAS 7-100. This document (⟶) is part of the Final Technical Report which consists of the following:

⟶ Vol. I	Summary

CAPSULE BUS SYSTEM

Vol. II, Section I	Capsule Bus
Vol. II, Section II	Preliminary Design for OSE
Vol. II, Section III	Implementation Plan
Vol. II, Section IV	Test Program

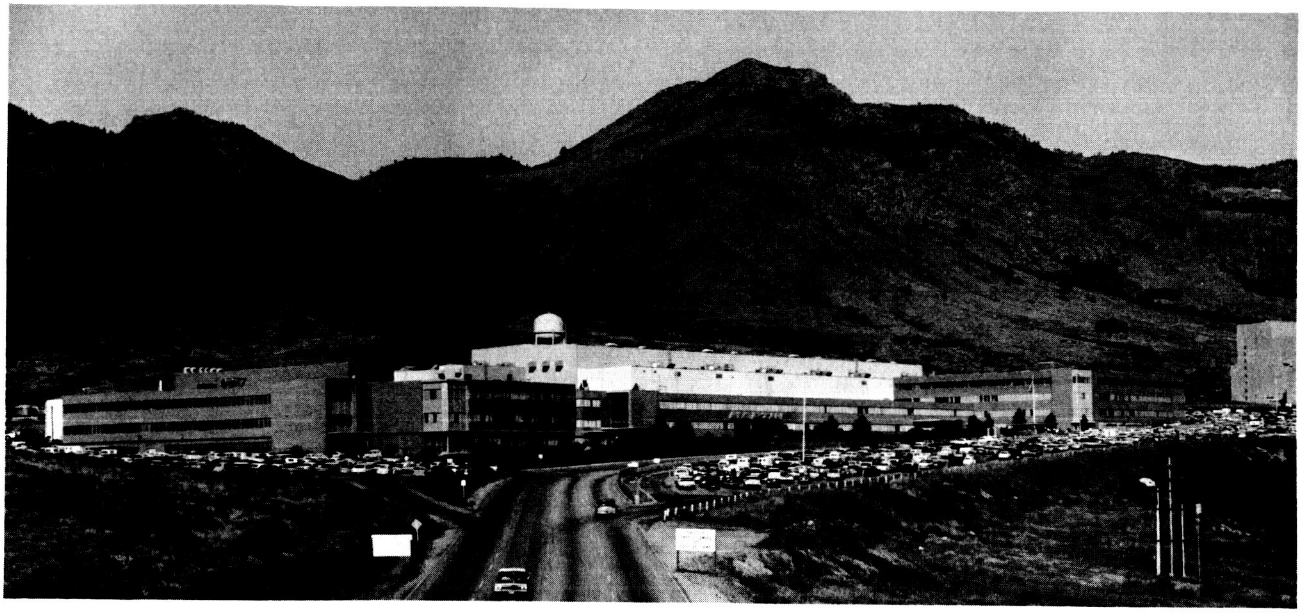
SURFACE LABORATORY SYSTEM

Vol. III, Section I	Surface Laboratory
Vol. III, Section II	Preliminary Design for OSE
Vol. III, Section III	Implementation Plan
Vol. III, Section IV	Test Program

ENTRY SCIENCE PACKAGE

Vol. IV, Section I	Entry Science Package
Vol. IV, Section II	Preliminary Design for OSE
Vol. IV, Section III	Implementation Plan
Vol. IV, Section IV	Test Program
Vol. IV, Section V	Entry Science Package Interfaces
Vol. V	Interface Descriptions
Vol. VI	RTG Report
Vol. VII	A Flight Capsule with RTG for 1973 Mission

Limited distribution on Volumes VI and VII has been made as directed by JPL.



Martin Marietta Plant at Denver, Colorado

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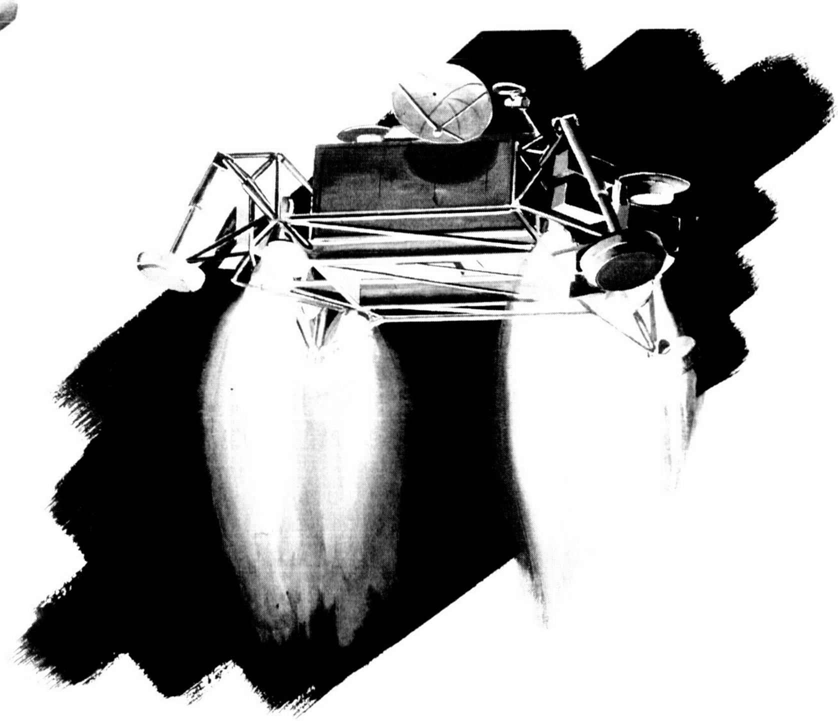


INTRODUCTION

This volume summarizes the Martin Marietta Phase B study of the Voyager Capsule Program -- a vital portion of one of the most sophisticated, complex, and exciting ventures ever undertaken by the nation. Our study is believed to be a complete response to the requirements of the Jet Propulsion Laboratory and the National Aeronautics and Space Administration. Specifically, in Phase B we have:

1) Selected a preferred configuration (see opposite page) that integrates automated spacecraft technology experience and emphasizes simplicity and reliability to ensure reasonable cost and availability for the 1973 launch opportunity

2) Studied other inviting configurations, including a ring lander and an RTG-powered alternative, which, although somewhat less conventional in approach, merit further consideration by NASA

3) Developed modularity and standardization that will provide effective, economical potential for missions in the next decade

4) Developed an understanding of the science objectives, the hardware to achieve the objectives, and their interplay and influence on the Capsule

5) Conducted the other systems and technological studies required by the contract

6) Reported the results in Volumes II through VII of the final report.

We have focused appropriate attention on exercising technological leadership of the major subcontractors, whose spacecraft experience contributions to the Phase B studies have been substantial and highly commendable:

RCA Astro-Electronics Division in telecommunications

NAA Autonetics Division in guidance sensor subsystem

Bendix Aerospace Systems Division in science systems and general assistance on the Surface Laboratory System

Hughes Aircraft Space Systems Division in applicable Surveyor experience.

Our experience with these subcontractors in Phase B convinced us that their combined backgrounds and Martin Marietta experience provide that strength of automated spacecraft capability demanded by the Voyager Flight Capsule System.

In the following sections, we give prominence to a summary of the technical highlights of the Phase B studies. We have also presented separate discussions of various specialized technical areas -- as well as certain management areas where these contribute to an understanding of our approach in bridging the gap between previous performance and the Phases C and D that follow.

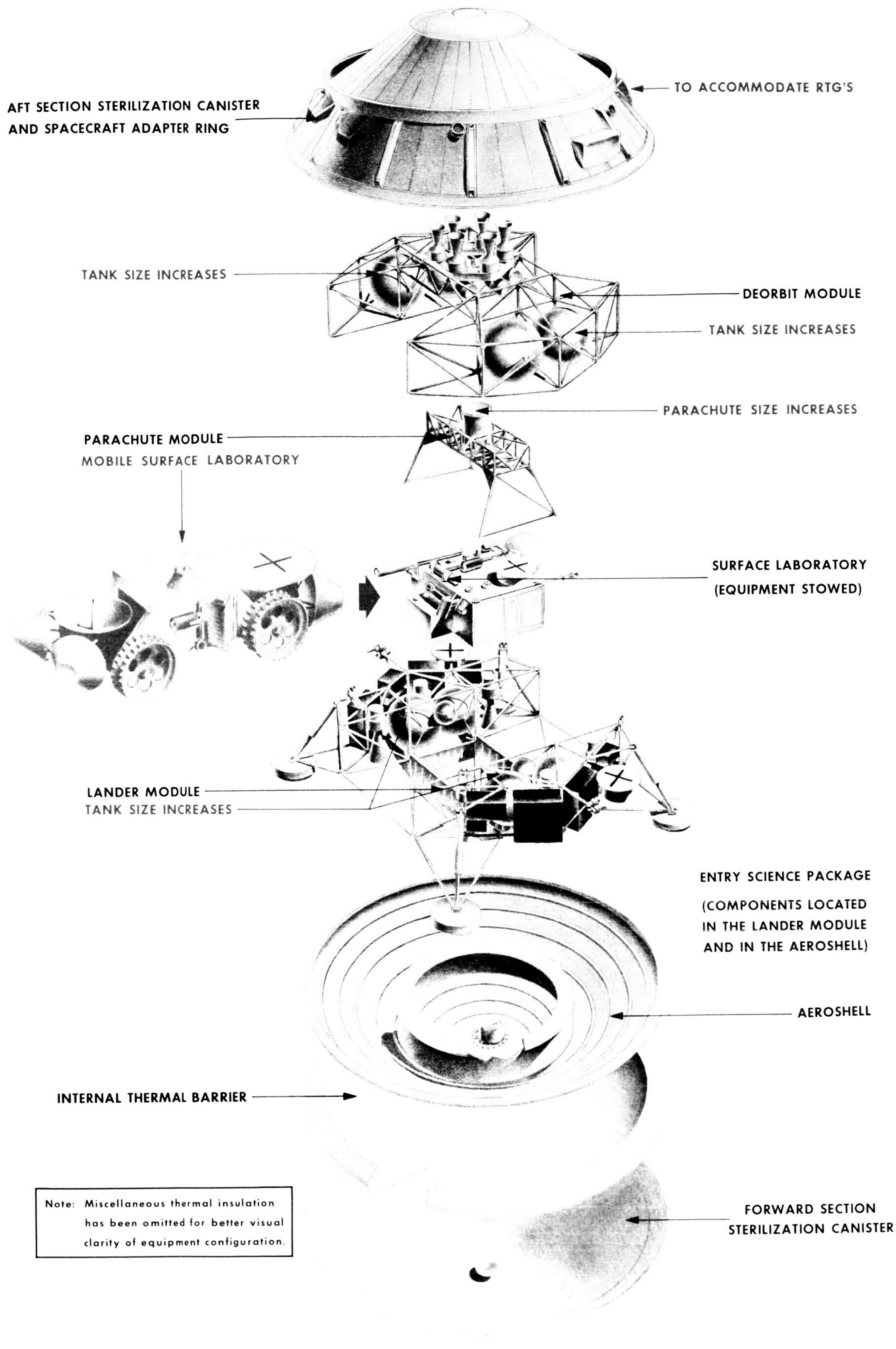


Fig. 1. Preferred Configuration and Standardization Concept (Items Standard for the Decade Are Shown in Black)

I. TECHNICAL HIGHLIGHTS

A Voyager Flight Capsule System meeting all mission requirements can be developed for the 1973 launch opportunity. Martin Marietta's preferred design for the Flight Capsule (Fig. 1) weighs 4980 pounds. This includes a 6% weight contingency and a combined Entry Science Package/Surface Laboratory weight of 1002 pounds. Its basic characteristics and weight status are shown below.

	Weight (lb)	Features		
FLIGHT CAPSULE SYSTEM	**4980**			
Weight Contingency	314			
Adapter/Canister	625			
		Deorbit	Aeroshell	Terminal Descent and Landing
Capsule Bus	3039	Six 1400-lb thrust engines Hydrazine mono-propellant	70° half-angle cone Cork-based heat shield	Subsonic-type parachute Six 1400-lb thrust engines Throttle ratio 12:1 Hydrazine mono-propellant Monopropellant attitude control system Four crushable honeycomb landing legs
Entry Science	142	Modular design 71-lb scientific instruments and supporting equipment 5 million bits of science data, including TV		
Surface Laboratory	860	Modular design 165- lb scientific instruments and supporting equipment 50-hour surface life 5 to 20 million bits per day of science data, including TV		
Standardization		Surface Laboratory/Capsule Bus interface Flight Capsule systems as shown in Fig. 1		

DESIGN FOR MISSION SUCCESS

The selection of this configuration and its subsystems is based on achieving the highest probability of mission success within the performance requirements and weight limitations. Particular emphasis has been given to achieving a design that has "no single malfunction that would cause the loss of the mission, or of all of the scientific data." Designing for mission success led to the choice of:

- Low ballistic coefficient entry configuration
- Parachute/vernier terminal descent system: (1) hydrazine monopropellant; (2) engine-out capability
- A multiplicity of measurements for each of the pertinent Mars atmospheric properties
- Three Surface Laboratory communication links to ensure return of scientific data.

Low Ballistic Coefficient

In the initial phases of every new program, there are unknowns that materially affect the design of the system. One must therefore achieve a system design that is insensitive to these unknowns. Relative to the design of the Voyager Flight Capsule configuration, the principal unknowns are the Martian atmospheric and surface conditions. The approach taken is illustrated in Table 1.

TABLE 1. APPROACH TO DESENSITIZE DESIGN TO UNKNOWNS

PARAMETER	DESIGN IMPLICATION	SOLUTION	PREFERRED CONFIGURATION
A. ORBIT EPHEMERIS UNCERTAINTY	Potentially steep entry flight path angles (-20 deg) result in high terminal phase initiation velocity	1. Minimize entry ballistic coefficient by providing: a. High drag entry vehicle b. Large drag area c. Minimum entry weight consistent with performance requirements	1. $M/C_DA = 0.2$ a. 70 deg half-angle cone $C_d = 1.64$ b. 19 ft diameter c. Stage deorbit module
B. ATMOSPHERIC SCALE HEIGHT & PRESSURE/ DENSITY PROFILE	High pressure/density and/ or scale height result in high terminal phase initiation velocity		
C. LANDING ELEVATION RELATIVE TO MEAN SURFACE LEVEL	Terminal phase initiation relative to local surface level results in increased terminal phase initiation velocity with increased altitude	2. Minimize altitude required to perform terminal descent maneuver	2. Maneuver initiated at 18,000 ft above actual terrain a. M 1.6 parachute with large drag area b. Six 1400-lb vernier engines; 12:1 throttle ratio
D. ATMOSPHERIC COMPOSITION	Terminal phase initiation as a function of Mach number is uncertain	Initiate terminal descent as a function of altitude above local surface	Altitude marking radar
E. SURFACE SLOPE & DISCONTINUITIES	Landing instability results from touchdown on steep slopes and discontinuities	1. Maximum stability 2. Avoid steep slopes and discontinuities	1. Four legs and cg height control 2. Mechanization of Terminal Descent Guidance to seek level surface 3. Optical correlator terrain roughness sensor merits further consideration

We have achieved a ballistic coefficient of 0.2 slug per square foot by staging the deorbit module to reduce the entry vehicle weight to 3000 pounds, and by the selection of a high-drag 70-degree half-angle cone, 19 feet in diameter. This configuration provides the necessary deceleration from atmospheric entry (800,000 feet) to the altitude/velocity conditions for parachute deployment (18,000 feet above the surface, Mach 1.6 or less) for all postulated Martian atmospheres.

Parachute/Vernier System

Choice of a parachute/vernier system for terminal descent was also based on achieving a design insensitive to the unknowns. An all-retro system would have to carry an excess of reserve propellant to account for atmospheric uncertainties. The selected system is "forgiving" in this respect in that only the time on the parachute necessary to arrive at the proper altitude and velocity for vernier initiation changes with the different atmospheres postulated. The parachute is deployed on an 18,000-foot altitude signal from the radar. Vernier ignition is based on a 4000-foot signal; throttling is controlled on the basis of velocity and range to go. This system has the capability for landing on surfaces at the stipulated two kilometers above the mean Martian surface level.

The choice of the hydrazine monopropellant over the higher performance bipropellant was based on achieving a more reliable design. The monopropellant system has but half the components of a bipropellant system to meet the Voyager performance requirements because of better propulsion-system mass functions. The provision of engine-out capability further increases the probability of mission success.

Multiplicity of Entry Measurements

As the primary objective of the Voyager Program is the scientific exploration of Mars, heavy emphasis has been placed on acquiring and returning this scientific data.

Relative to the structure of Martian atmosphere, a number of techniques have been incorporated in the design to determine each of the pertinent atmospheric properties. These techniques and the measurements required are shown in Fig. 2. They involve a combination of measurement of entry vehicle conditions (e.g., deceleration, attitude), direct measurements of atmospheric properties, reconstruction of the entry trajectory, and atmosphere structure profiles. This combination of measurements has been successfully accomplished in Martin Marietta's PRIME Program for the Air Force.

Ensure Return of Surface Data

Scientific experiments in the Surface Laboratory cover the spectrum of visual imaging, atmospheric and soil sampling, and life detection as shown in Table 2. A number of the specific instruments are used in more than one capacity in this spectrum. In order to ensure the complete return of all of the data collected, three separate communication links have been provided for data return. These are: a high-gain S-band link incorporating a 30-inch parabolic dish that has the ability to transmit 448 bits per second directly to the DSIF. A UHF link is also provided to relay all of the Surface Laboratory data through the orbiting spacecraft at 3600 bits per second.

A second S-band link is provided for backup. This is an M'ary FSK noncoherent link capable of transmitting 2 bits per second directly to the DSIF.

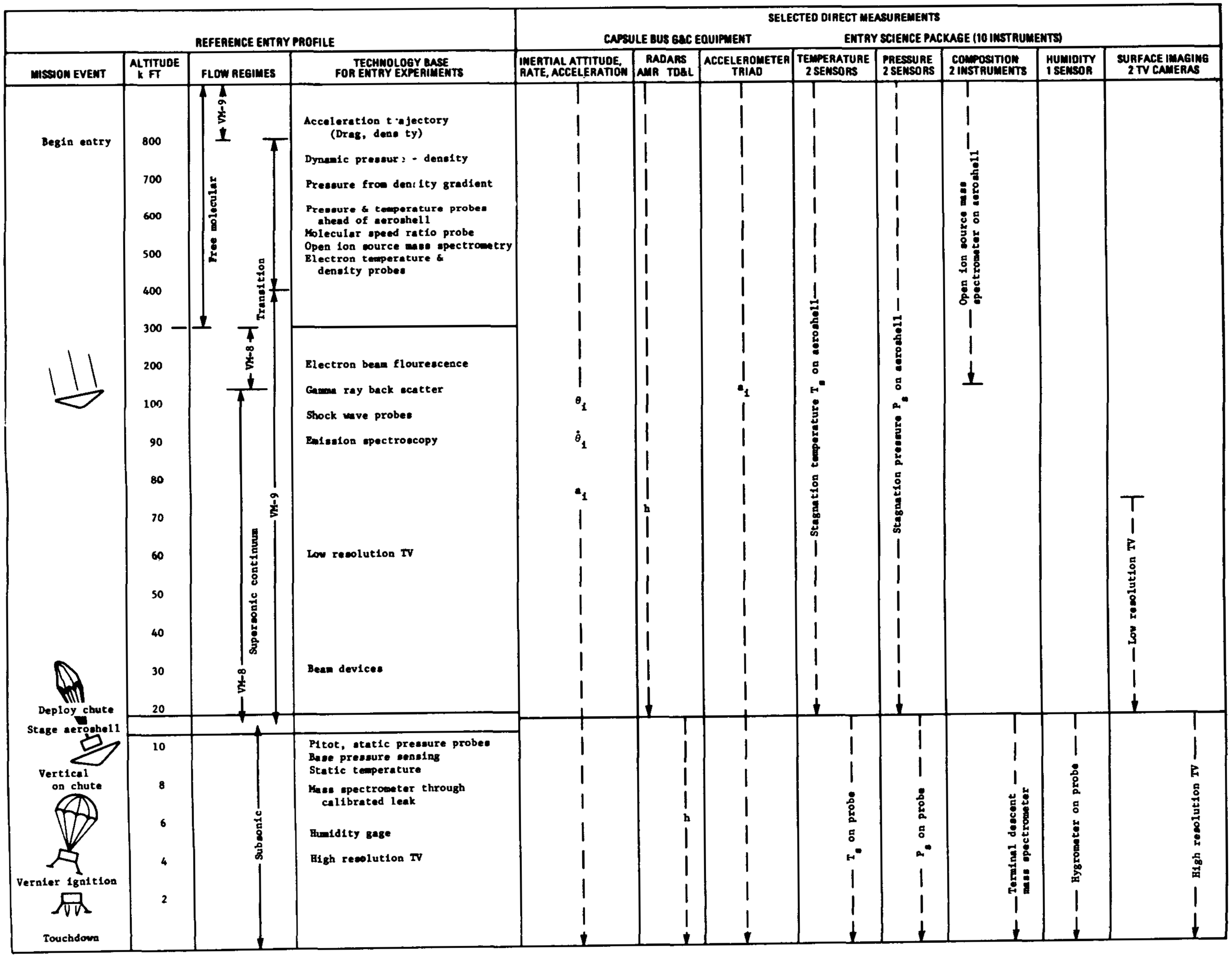


Fig. 2. Entry Science Measurements

TABLE 2. SURFACE LABORATORY EXPERIMENTS

EXPERIMENT	INSTRUMENT	ASSOCIATED BIOLOGICAL EXPERIMENTS
Visual Assay		
Local topographic photography with high and low resolution capability	Vidicon TV	1) Visual assay for life forms
Physical Environment		
Near surface atmospheric pressure, temperature, water vapor and wind	Atmospheric package	2) Assay gross biological environment
Incident solar flux	Multichannel radiometer	Assay gross biological environment
Subsurface temperature	Temperature probe	3) Assay for possible favorable subsurface micro-environments
Chemical Environment		
Near surface and subsurface atmospheric composition including minor constituents	Gas chromatograph/mass spectrometer	4) Detection of gaseous components indicative of organic activity
Organic compounds in surface soil	Gas chromatograph/mass spectrometer	5) Identification of wide variety of organic molecules in a soil sample by "Fingerprint" technique
Elemental composition of surface soil	Alpha-scatter spectrometer	Inorganic salts
Life Detection		
Specific life detection with simple culture experiments	Metabolism detector	6) Detection of breakdown of carbohydrate cultures by micro-organisms on the surface
	Biological analyzer	7) Analysis of soil
		8) Sample for narrow class of organic compounds

Subsystems Design Approach

In designing for mission success, each of the subsystems has been similarly affected. Indeed, the design of an unmanned automated system for mission success involves a number of design principles:

- Anticipation of all functional requirements
- Design margins over expected environments
- Alternative path functional redundancy
- Fault protection
- Block redundancy
- Cooperative multichannel operation

The manner in which these principles have been applied to landed science, entry science, and the subsystems of the Voyager Flight Capsule is summarized under "Key Features and Technology Status."

Technology Base

Voyager is the largest and most complex unmanned spacecraft program yet undertaken by NASA. The Flight Capsule represents the first attempt to land on another planet after first traversing its atmosphere. At the same time, its design and development culminates in flight readiness within a two-month span in the summer of 1973. Our confidence that our preferred Flight Capsule System design can be developed for the 1973 launch opportunity is based on the fact that its technology base is found in past flight programs and in development programs already underway.

Surveyor/LEM

Terminal descent radar

Landing legs

Surface Laboratory experiment integration

Ranger

Television

Mariner

Telemetry

S-band communications hydrazine monopropellant system

TIROS/Relay

UHF communications

Minuteman

Gyros

Computer

Titan III

Attitude control system

ALSEP

Landed science data subsystem

Parachute

PEP Program--Langley Research Center

Sterilizable Propulsion Systems

Sterilizable liquid--Jet Propulsion Laboratory

Sterilizable Piece Parts

Approved piece parts list--Jet Propulsion Laboratory

MISSION CAPABILITY AND SEQUENCE

Launch of the two complete planetary vehicles on a single Saturn V vehicle will be accomplished between July 13 and September 7 in 1973. The two planetary vehicles will be separated from the Saturn IVB stage so as to arrive at Mars at least eight days apart. During the nominal seven-month flight to Mars, the Flight Capsule will be enclosed in its sterilization canister, as shown in Fig. 3. Ground commands to the Flight Capsule and systems status from the Flight Capsule are transmitted via the Spacecraft. Flight Capsule thermal control is maintained by a combination of thermal blankets and electric heaters powered from the Spacecraft. Jettisoning of the sterilization canister occurs just prior to insertion into Mars orbit. This point was selected as giving the highest probability that the canister would not impact and contaminate the Martian surface.

The Flight Capsule design can accommodate a Mars orbit periapsis between 800 and 1800 kilometers, an apoapsis between 8500 and 16,500 kilometers, and an orbit inclination between 30 and 70 degrees, and still accomplish its mission of landing on the Martian surface and returning all data collected during entry and surface operations. The design capabilities of the Capsule to accommodate this range of conditions are:

1) Up to 10 hours deorbit--entry coast time

2) Landing site longitudinal control of 30 degrees

3) Flight Capsule leads Spacecraft nominally by 10 degrees for good communications during entry and after touchdown

4) Nominal eight minutes communication with the orbiting Spacecraft after touchdown.

The deorbit-entry sequence (Fig. 4) includes a 30-minute delay between the separation and deorbit maneuvers to preclude the deorbit exhaust impinging on the

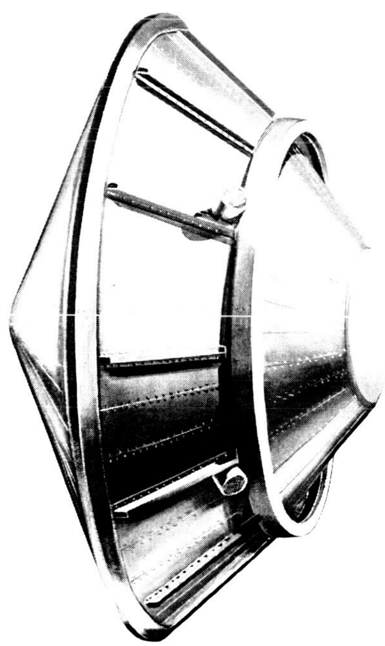


Fig. 3. Configuration for Flight to Mars

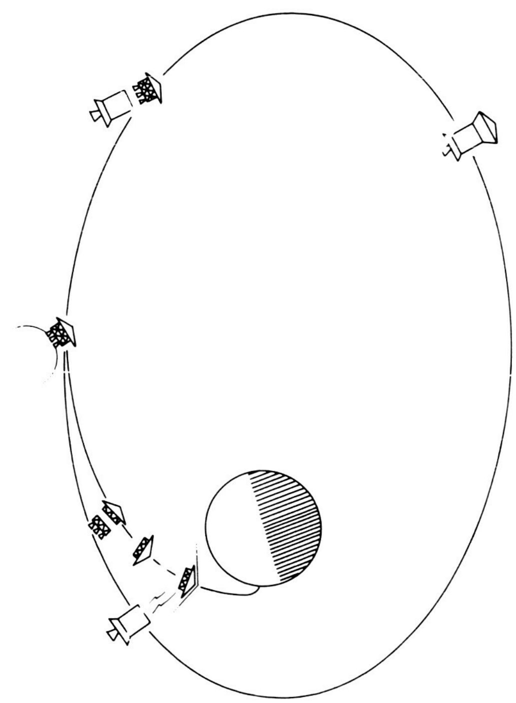


Fig. 4. Deorbit Entry Sequence

Spacecraft surfaces. Following the deorbit maneuver (Fig. 5), the entry configuration (Fig. 6) is achieved by staging the deorbit module. Flight Capsule attitude is maintained for ease of communication with the orbiting Spacecraft during the subsequent coast period. Ten minutes prior to entry, the Capsule is reoriented to the entry attitude on sequencer initiation. Entry science instruments are initiated at 800,000 feet and measurements taken as shown in Fig. 2. Television is turned on at 75,000 feet. Parachute deployment is initiated 18,000 feet above the surface on a signal from the altitude marking radar. At this point, the Mach number is between 0.8 and 1.6 for all postulated atmospheres. A number of parachutes have successfully operated in this Mach range in the NASA Planetary Entry Parachute Program.

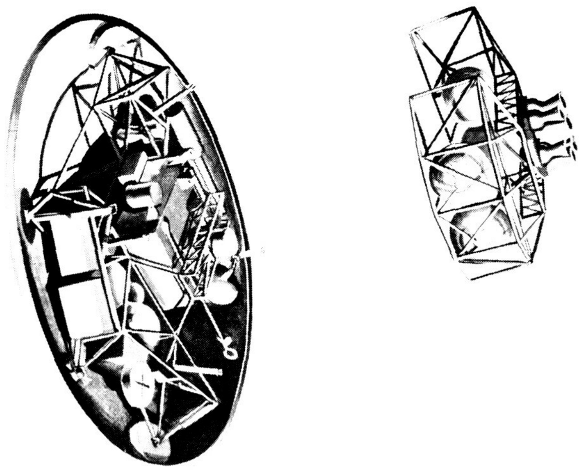


Fig. 6. Entry Configuration

Aeroshell staging is delayed 7 seconds after chute deployment (Frontispiece, page iv) to ensure a subsonic separation and the proper drag-to-weight ratios between the parachute lander and the aeroshell. The four landing legs are deployed at this point, and control of the Flight Capsule is switched to a 5-beam terminal descent and landing radar. The five beams are in themselves redundant as all measure both range and velocity of the Flight Capsule with respect to the Mars surface. Velocity measurements are used to control the thrust of the vernier engines in canceling the effects of winds up to 220 feet per second. In this environment, the horizontal velocity at touchdown can be reduced to less than 5 feet per second. Range and velocity measurements are both used to throttle the vernier engines in controlling the vertical descent of the Flight Capsule.

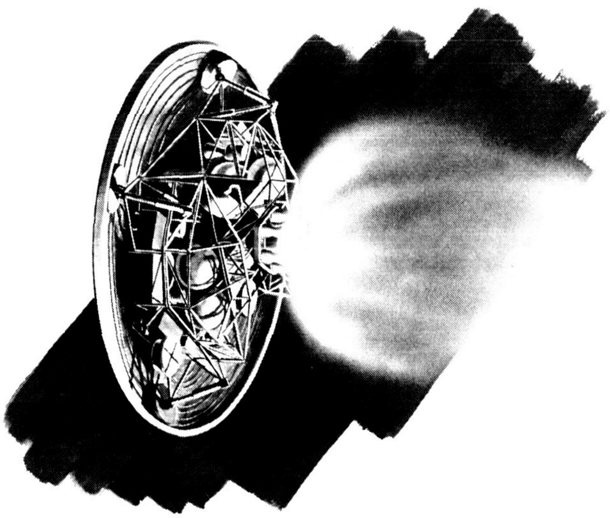


Fig. 5. Deorbit Maneuver

Ten feet above the surface (Fig. 7), the vernier engines are shut off, and the Surface Laboratory is initiated. The unpowered 10-foot drop results in landing velocities to 18 ± 5 fps vertically and 0 ± 5 fps horizontally in a 220 fps wind.

Following touchdown (Fig. 8), Surface Laboratory experiments are activated, and initial data relayed to the orbiting Spacecraft within the first eight minutes. A typical sequence of events during the 50-hour, two-diurnal-cycle operation period is shown in Fig. 9. This sequence results in between 5 to 20 million bits of data being collected and returned to Earth daily.

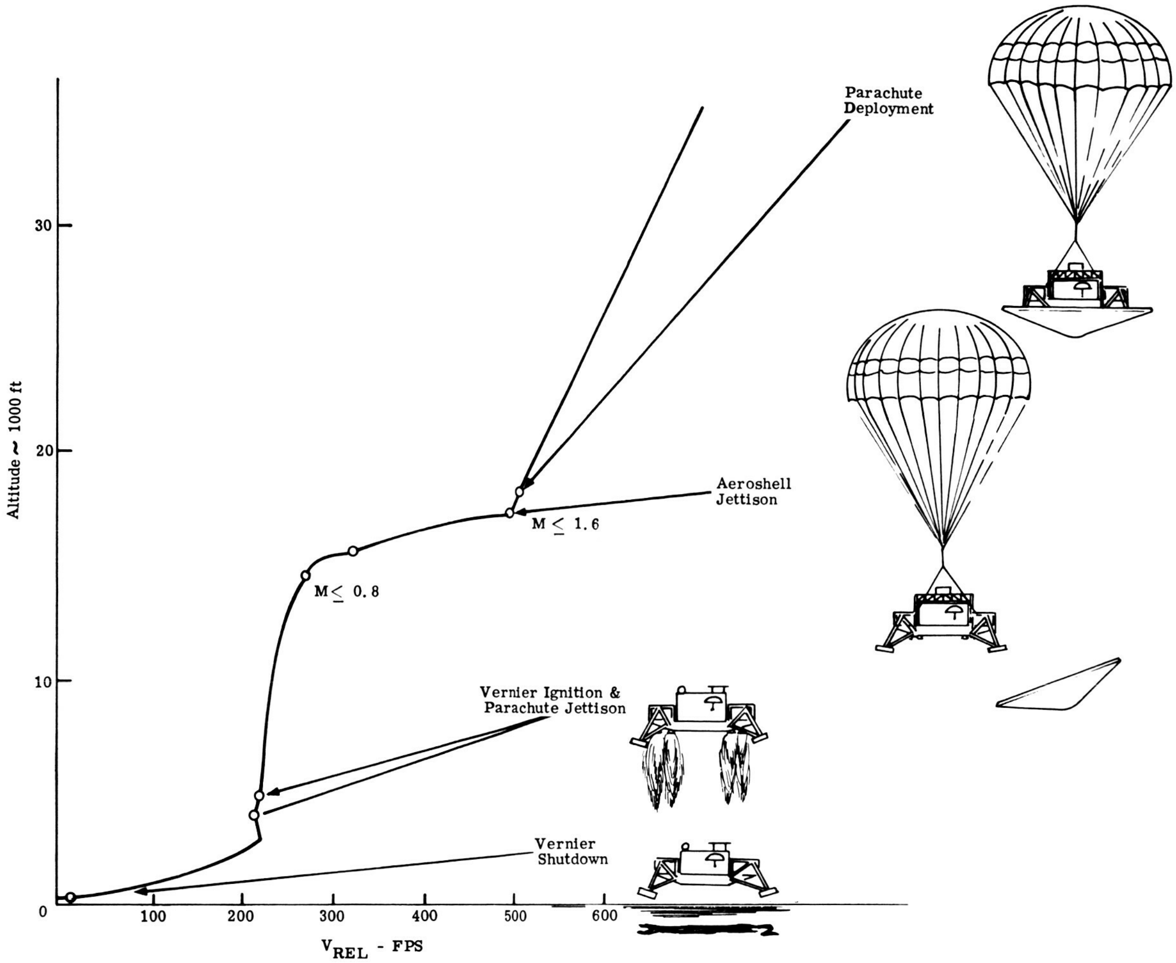


Fig. 7. Terminal Descent Sequence

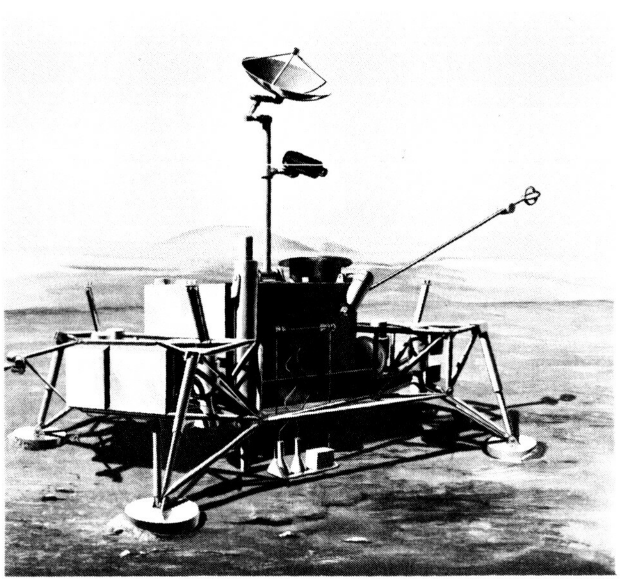
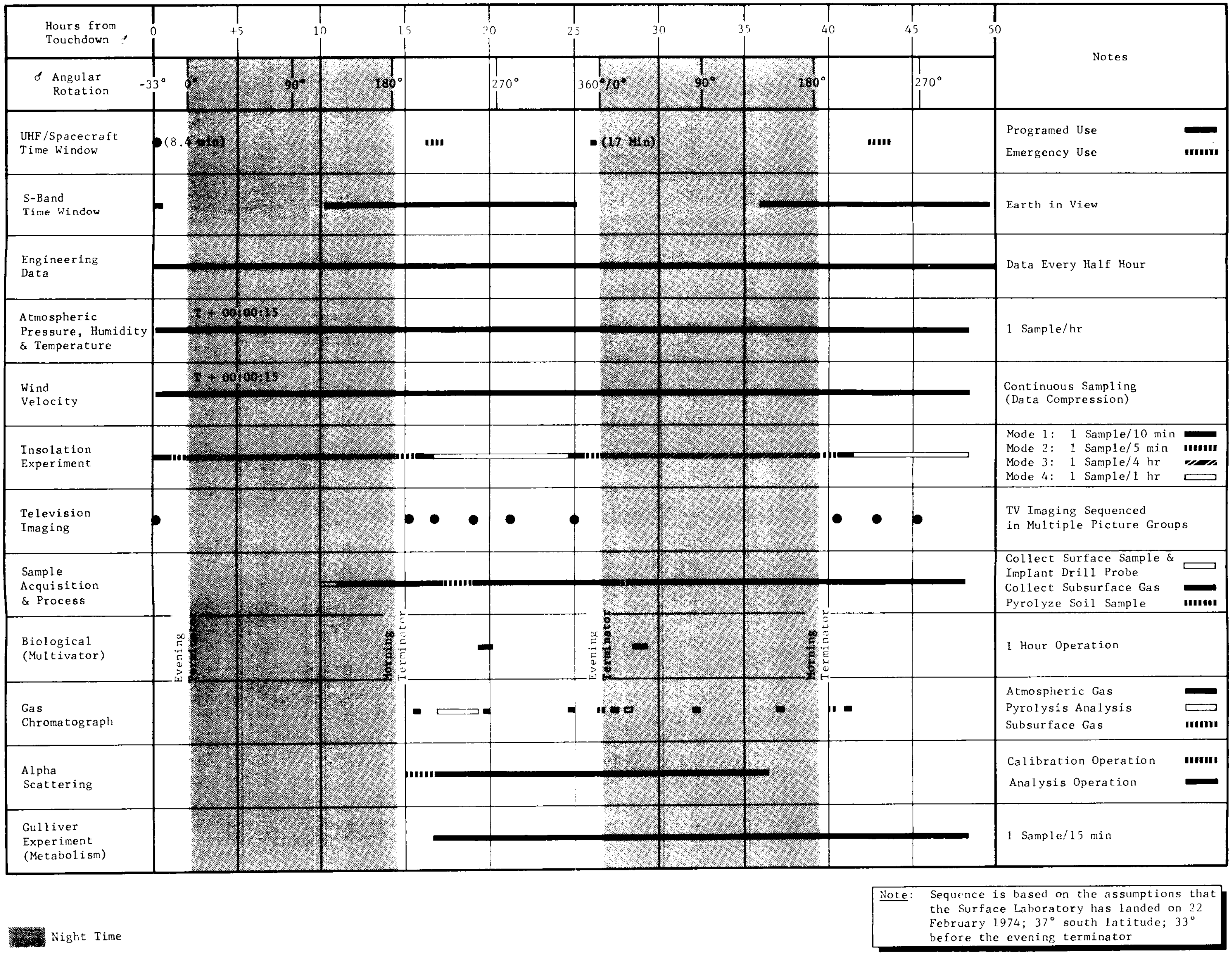


Fig. 8. Landed Configuration



Note: Sequence is based on the assumptions that the Surface Laboratory has landed on 22 February 1974; 37° south latitude; 33° before the evening terminator

Fig. 9. Typical Surface Laboratory Sequence of Events

DESIGN RATIONALE

Our preferred configuration also reflects consideration of:

- Standardization of the Capsule Bus for the decade
- Modularity of the Capsule Bus/Entry Science Package/Surface Laboratory
- Sterilization
- Cost

Standardization

The degree of standardization beteeen the 5000-pound Flight Capsule for 1973 and the 7000-pound Flight Capsule for later missions is shown in Fig. 1. Deorbit/vernier engines have been sized for the 7000-pound system (1400 pounds thrust), as has the attitude control system. The geometry of the Capsule Bus/Surface Laboratory interface has been standardized to the requirements of a mobile Surface Laboratory for later missions. Mechanical interfaces consist of three attachment points on the lower cross beams, while electrical connections are accommodated through standard plugs.

Thermal interfaces have been standardized by thermally isolating the Capsule Bus and the Surface Laboratory. This has been accomplished by the use of insulation in each unit in the same manner that the Flight Capsule has been thermally insulated from the Spacecraft during the flight to Mars.

Changing from a fixed Surface Laboratory in 1973 to a longer life mobile Surface Laboratory for later missions involves a change from batteries to RTG's as a primary source of power and implies changes in the science subsystems. However, the designs of the command and sequencing and the pyrotechnics subsystem have been standardized for both laboratory concepts for the decade. The 150-pound weight penalty of these standardization decisions is included in the 4980-pound Flight Capsule.

In short, future design changes for the decade are limited to the increased sophistication expected in scientific exploration (instrument changes and laboratory mobility) and an increased communication capability (48-inch antenna, 50-watt TWTA, and data coding). The capacity of the Capsule Bus Systems, such as deorbit/vernier propellant tanks, and the size of the parachute must also be increased to accommodate the expected weight growth. Weight provision for these expected future design changes has not been included in the 4980 pounds.

Modularity

There is little weight penalty in adapting a modular design to each of the three major Flight Capsule systems (Capsule Bus/Entry Science Package/Surface Laboratory). The flexibility in mission planning and execution is, on the other hand, immeasurably enhanced. The modularity concept of our preferred configuration (Fig. 10) is based on three primary considerations:

1) Position indications along the entry trajectory required by the Entry Science Package will be provided by the Capsule Bus System rather than duplicate the equipment in the other modules

2) All preseparation systems monitoring, Flight Capsule updating, and battery charging will go through the Capsule Bus, simplifying the Flight Capsule/Spacecraft interface

3) System interfaces are held constant while retaining the capability for system flexibility.

Two decisions--powering the Entry Science Package from the Capsule Bus and the degree of modularity of the communications system--deserve discussion.

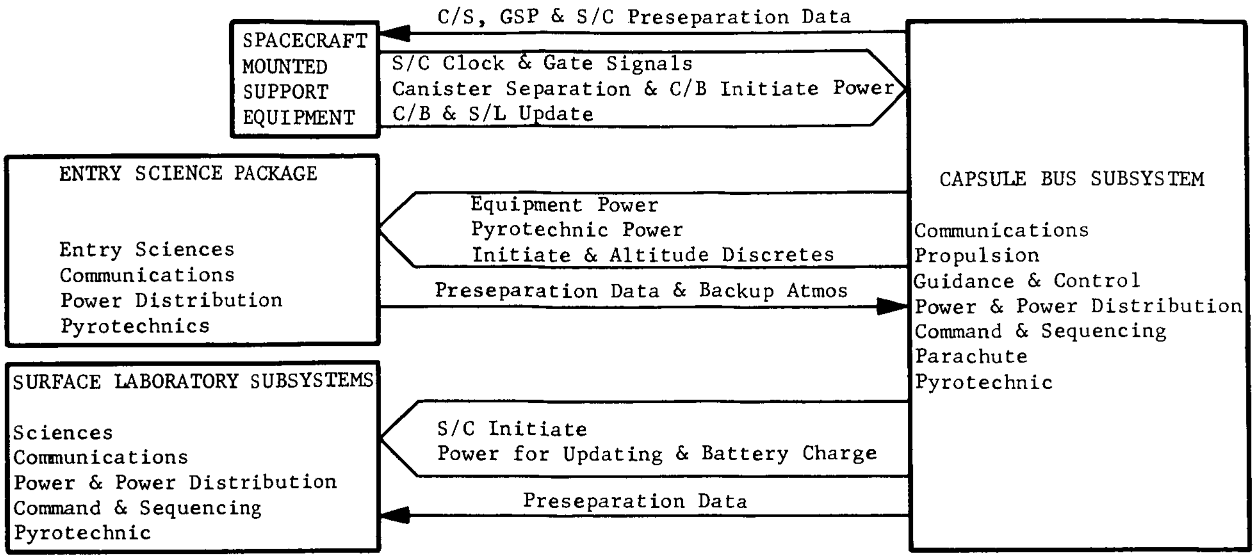


Fig. 10. Modularity of Entry Science Package, Capsule Bus, and Surface Laboratory System

The Entry Science Package can, of course, have its own batteries for both equipment and pyrotechnic power. However, this complicates rather than simplifies the Capsule Bus/Entry Science Package interface. This comes from the requirement to status battery condition following the heat sterilization process. Temperature, current, and voltage of each individual cell must be measured to determine battery condition following sterilization. As all Flight Capsule Systems status measurements are brought out through the Capsule Bus, this means that 100 wires would have to cross the Entry Science Package/Capsule Bus interface to properly monitor Entry Science Package power sources. As the Entry Science Package power requirements are only 60 watt hours, or less than 2% of the Capsule Bus requirements, it can be powered from the Capsule Bus power sources without affecting the reserve in that system. In contrast to the 100 wires required for monitoring separate power sources for the Entry Science Package, only four are required to power this package from the Capsule Bus.

In addition to the simpler interface, powering the Entry Science Package from the Capsule Bus also results in a 40-pound weight savings. Removal of the Entry Science Package for later missions leaves the Capsule Bus power sources unchanged.

It is quite obvious that the same rationale could be applied to powering the Entry Science Package from the surface Laboratory. This was considered and rejected, because it required activating the Surface Laboratory at entry rather than at touchdown as desired. Activating the Surface Laboratory at entry was rejected as it increases the potential failure modes. Inadvertent antenna deployment or soil drill operation would be catastrophic. Inadvertent activation of the Surface Laboratory UHF link would directly interfere with the Capsule Bus UHF link. All of these potential failure modes are avoided in the preferred design.

Our preferred design, therefore, has the Entry Science Package powered from the Capsule Bus batteries.

The second decision is that of carrying separate UHF systems for the Capsule Bus/Entry Science Package/Surface Laboratory System for communication with the orbiting Spacecraft. Quite obviously these could be combined into a single system, and at a weight saving. However, the interfaces become extremely complex. Data rates of the separate modules are quite different; power for the single system would have to be switched on landing from the Capsule Bus to the Surface Laboratory. This results in a more sensitive grounding system and suggests an integrated power supply, which had adverse ramifications on the mobility concept for later missions. These considerations, and the restrictions imposed on later flexibility, led us to the three separate systems. The attendant weight penalty of 22 pounds for the separate UHF systems is included in the 4980-pound system weight.

Sterilization

Planetary quarantine, sterilization, and the heat sterilization process have been a factor in the selection of all Flight Capsule systems and components. These considerations have uniquely determined the:

1) Design of the sterilization canister

2) Decision to jettison the canister just prior to Mars orbit insertion, which imposed the

3) Need for a thermal blanket outside the canister

4) Design pressure of all tankage

5) Need for a complete Flight Capsule checkout following sterilization, which imposes

6) Design requirements on Operational Support Equipment to accomplish systems checkout while in the canister.

Sterilization considerations for Capsule electronics are principally in the choice of piece parts and materials, rather than a subsystem choice *per se*. Accordingly, we have a policy for selection, test, and control of piece parts and materials for both ourselves, major subcontractors, and vendors. This policy of designing only with the approved piece parts and materials involves lot buying and qualification of piece parts, and a single source distribution of these qualified parts for the fabrication of all Voyager Capsule components.

Unlike Flight Capsule electronics, sterilization requirements were a factor in the selection of some of the mechanical subsystems, e.g.:

Deorbit and vernier propellants

Hydrazine sterilizability demonstrated

Higher-performance, solid-propellant failure modes (cracks and separation from binder) aggravated by heat sterilization

Oxidizer in higher performance bipropellant reacts chemically, in a manner not well understood, with other materials at sterilization temperatures (JPL Contract 951709)

Gyro Selection

G-10 gyros filled with inert gas rather than flotation fluid

Cost

Cost, *per se*, was not the determining factor in the selection of any subsystem, but it was a factor in all decisions. For example, the hydrazine monopropellant systems chosen for the deorbit and vernier modules are simpler than bipropellant systems. The monopropellant systems, incorporating the same engines in both the deorbit and the vernier modules, can be developed for one-fifth the cost of comparable bipropellant systems, resulting in savings of $10's of millions. The combination of solid deorbit rocket/liquid-propellant vernier would be the most expensive as two separate engines would have to be developed.

KEY FEATURES AND TECHNOLOGY

The following presents the key features and technology status of the Entry Science, Landed Science, and the subsystems of the Capsule Bus System. The interrelationship of these systems is shown in Fig. 11.

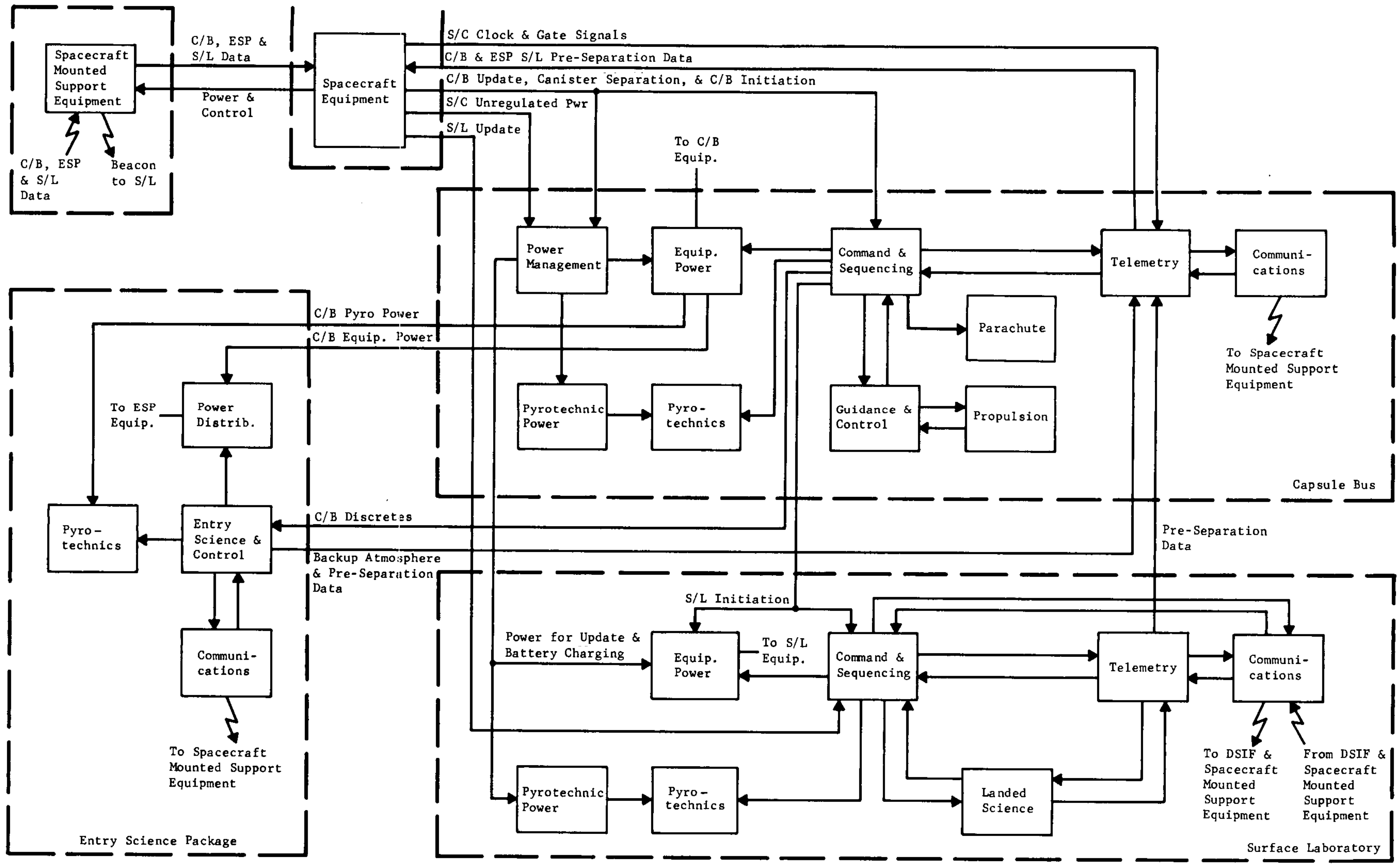
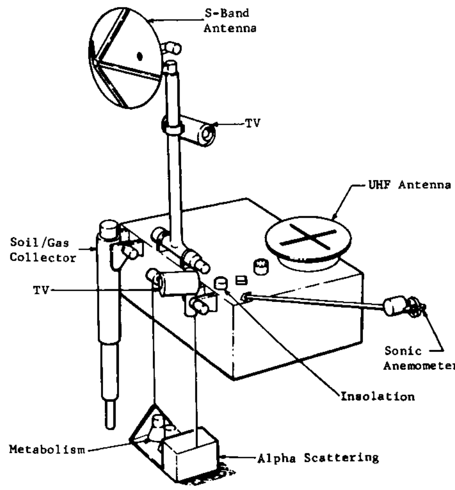


Fig. 11. Interrelationship of the Entry Science Package, Surface Laboratory System, and Capsule Bus System

LANDED SCIENCE



Key Features:

1) Redundancy in acquisition of data

Two TV cameras

Multichannel radiometer

Gas chromatograph, mass spectrometer independent of tandem usage

Eight analyses for each of three soil samples

Multiple sources and detectors in α scattering spectrometer

Backup environmental sensors

2) Flexible Science Data System

GP computer--redundant

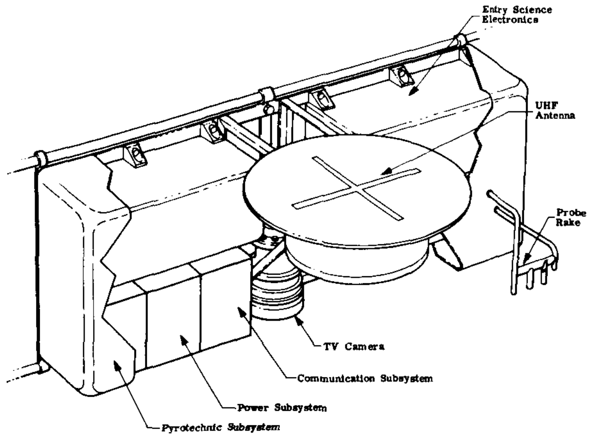
Remotely reprogrammable

Adaptive programs

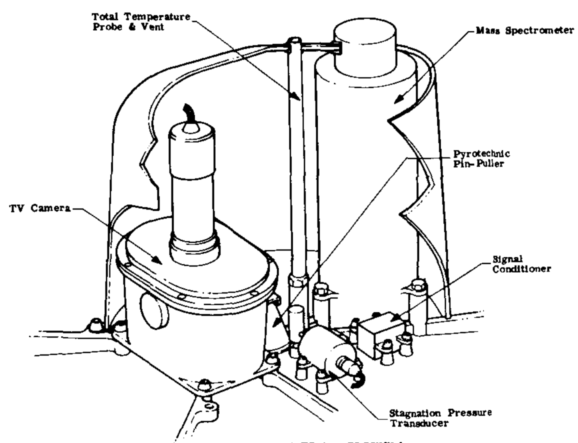
Data compression

KEY TECHNOLOGIES	DEVELOPMENT STATUS
Television	Vidicon flown on Surveyor, Lunar Orbiter, Mariner
Soil Drill	Lunar drill space-qualified by Martin Marietta
Surface Soil Collection	Surveyor
Tape Recorder	Sterilization not demonstrated
Gas Chromatograph	Surveyor prototype
Biological Analyzer	Breadboard tested
Subsurface Temperature	ALSEP Program
Other Instruments	Earth orbit satellites Sounding rockets High-altitude balloons

ENTRY SCIENCE



EQUIPMENT MOUNTED ON TRUSS



EQUIPMENT MOUNTED ON AEROSHELL

Key Features:

1) Redundancy in data acquisition

   Two TV cameras

   Two mass spectrometers

   Capsule Bus G & C accelerometer backup for ESP accelerometers

   Separate instruments before and after aeroshell staging

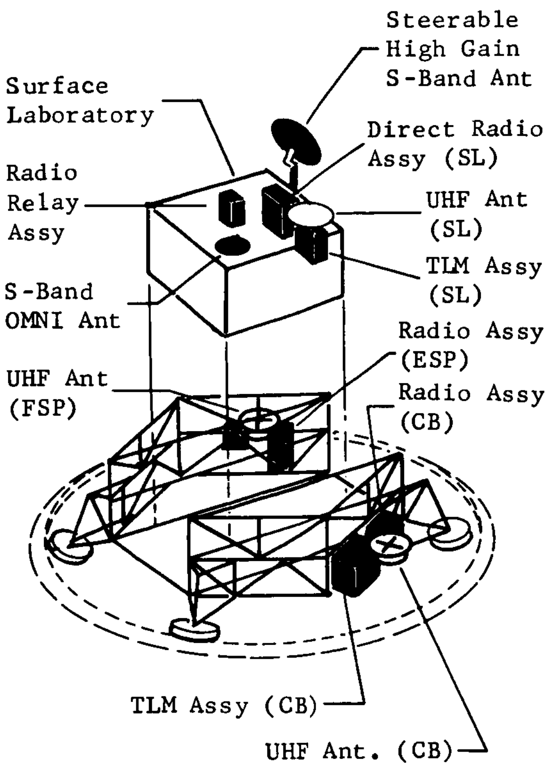
2) Science Data Subsystem

   Ten-bit encoding provides 0.1% accuracy of science data

   Minimum of 5.8×10^6 bits of data transmitted prior to landing

KEY TECHNOLOGIES	DEVELOPMENT STATUS
Trajectory Reconstruction	PRIME program by Martin Marietta
Pressure Transducer	Modified for sterilization by NASA Ames Research Center
Accelerometer	Bell Aerosystem has contract to modify for sterilization
Mass Spectrometer	Sterilizable type developed
Total Temperature and Humidity Sensors	Existing Sensors need verification of applicability

TELEMETRY AND COMMUNICATIONS SUBSYSTEMS

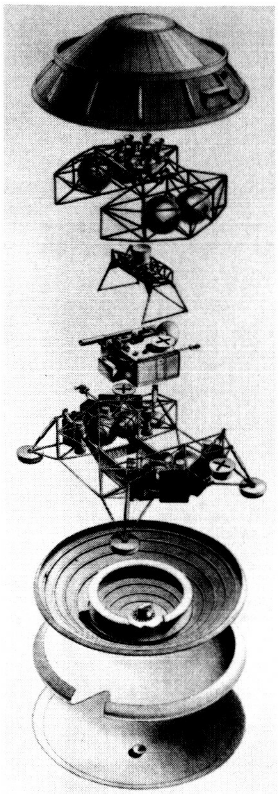


Key Features:

1) Up to 20 x 10^6 bits/day direct to DSIF
2) Backup links to ensure return of all scientific and engineering data
3) Capsule Bus and Entry Science Package UHF relay links--separation to landing
4) S-band link with 30-inch dish primary for surface laboratory
5) Surface laboratory backup links:
   a) UHF relay link,
   b) S-band link with omni-antenna
6) Data storage during blackout with delayed retransmission
7) Multiple data formats and sampling rates

KEY TECHNOLOGIES	DEVELOPMENT STATUS
S-Band TWT Amplifier	Mariner, Lunar Orbiter, and Apollo
M'ary FSK	Research by JPL; modulator breadboard by Martin Marietta
High Gain S-Band Antenna	
Drive Mechanisms	Surveyor and Lunar Orbiter
Electrical Design	Lunar Orbiter
Power Handling Capability of Antenna	Development tests performed by Martin Marietta in simulated Mars environment

STRUCTURAL SUBSYSTEM

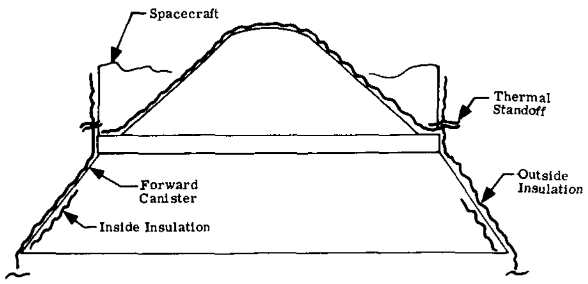


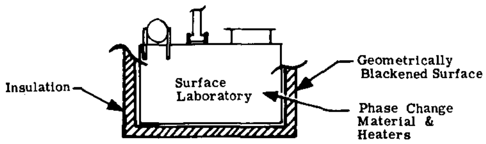
Key Features:

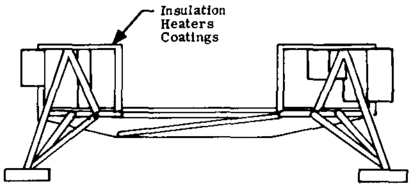
1) Frame stabilized beryllium skin aeroshell
2) Beryllium tubular trusses with aluminum fittings
3) Low density-high efficiency charring ablative material (SLA-561). Density 0.2 gm/cc. Effective heat capacity 7000 Btu/lb at 20 Btu/sq ft/sec input
4) Tankage and surface laboratory space provisions standardized for the decade
5) Standardized separation mechanisms
6) Self-venting canister providing quick-access separation joint
7) Four-legged crushable honeycomb landing system

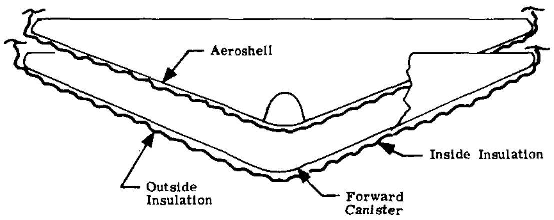
KEY TECHNOLOGIES	DEVELOPMENT STATUS
Frame stabilized cone structure	Scale model testing in progress--verification of the mathematical model
Low density ablator	Laboratory development phase complete--manufacturing processes currently being developed
Beryllium fabrication	Small planar truss fabricated and tested at Martin Marietta
	Beryllium laboratory available to investigate and develop processes for hot forming, drilling, and machining beryllium
Parachute	PEP and PRIME Programs--Martin Marietta
Touchdown system	Surveyor/LEM Technology Scale model testing at Martin Marietta

THERMAL CONTROL









Key Features:

This is a completely passive thermal control subsystem.

Capsule Bus

1) Insulation system for flight to Mars allows removal of the sterilization canister just prior to Mars orbit, minimizing the probability of contamination of the planet.

2) Passive control during deorbit and descent trajectory using coatings, insulation, and thermostatically controlled heaters.

Entry Science

1) Bulk of external science located in a single package with insulation and a thermostatically controlled heater.

Surface Laboratory

1) Design independent of wind velocity.

2) Design independent of dust erosion or accumulation.

3) Passive design using phase change material, heaters, and insulation.

KEY TECHNOLOGIES	DEVELOPMENT STATUS
Multilayer Insulation	JPL and Martin Marietta performance and sterilization development testing in progress.
Phase Change Materials	Used on Titan III Transtage. NASA study contracts.
Geometrically Blackened Surfaces	Preliminary dust accumulation and erosion testing completed by Martin Marietta.

PROPULSION SUBSYSTEMS

Key Features:

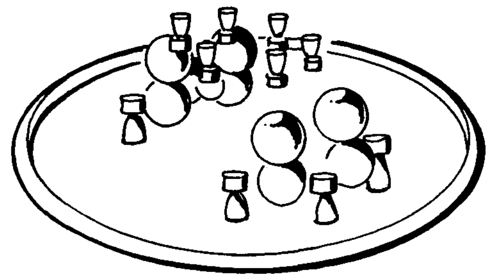
1) Monopropellant simplicity

2) Engine-out capability--without failure sensing

3) Blowdown pressurization--no gas regulators required

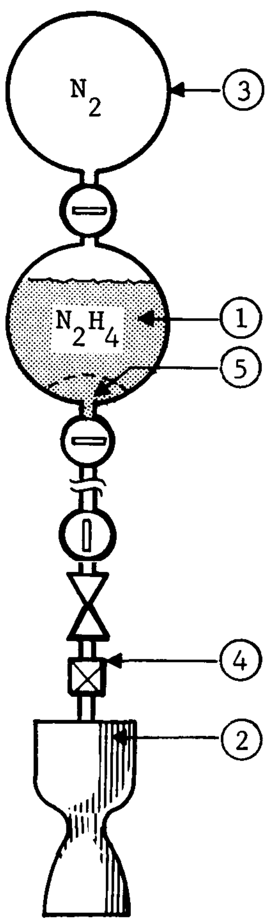
4) Throttle control of thrust vector--no separate thrust vector control system required

5) Capillary propellant control--no bladders required



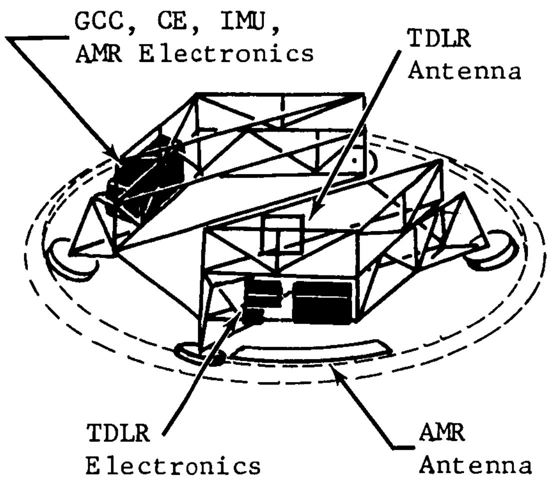
Functionally identical systems are used for deorbit and landing.

One engine development is adequate for both deorbit and landing; this can be standardized to the 1400 pounds required for the 7000-lb Voyager Capsule Bus System.



KEY TECHNOLOGIES		DEVELOPMENT STATUS	
	Req'd	Demonstrated	
Monopropellant Throttling	12:1	TRW	19:1
		Walter Kidde	22:1
		RRC	8:1
		Marquardt	4:1
High Thrust Monopropellant (lb)	1400	JPL (Gas Generator)	1000
		RRC (w/Throttling)	340
		Walter Kidde	300
		TRW (w/Throttling)	288
		Marquardt	100
Engine-Out Capability without Sensing		Titan III Transtage Monopropellant ACS--in Development	
Capillary Propellant Positive Control		In Development at Rocketdyne and Martin Marietta	
Loaded Sterilizability		Propellant Tankage, Hydrazine, Components	Martin Marietta Corporation-funded testing
Complete System		Monopropellant: JPL Testing	
		Bipropellant: Martin Marietta Testing Contract 951709	
Blowdown Pressurization		Titan II	
		Titan III Transtage Monopropellant ACS	

GUIDANCE AND CONTROL SUBSYSTEM



Key Features

1) No single catastrophic failure:

   Any two of three gyros

   Any three of five accelerometers

   Any four of five beams--Terminal Descent and Landing Radar

   General purpose digital computer--analog computer backup.

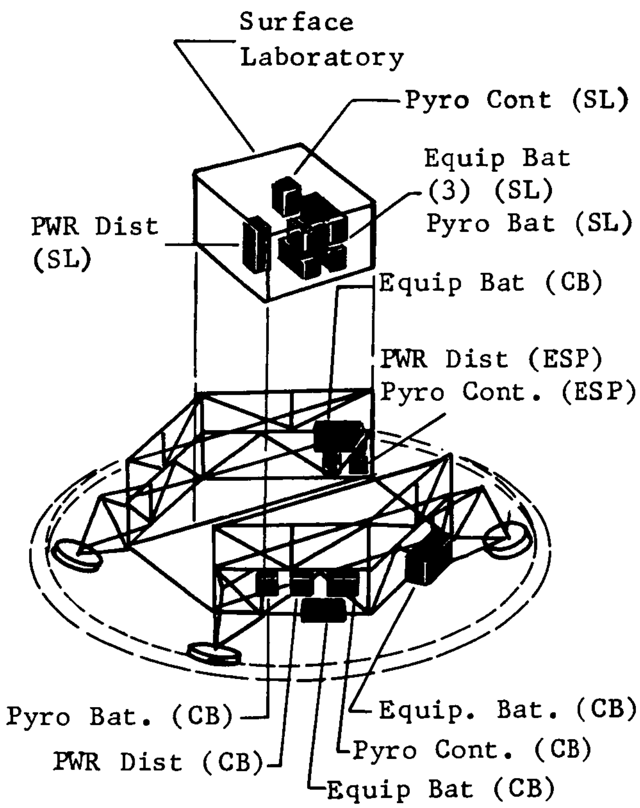
2) Remotely reprogrammable memory.

3) Terminal descent guidance mechanized to seek level surface.

4) Functional redundancy for critical sequencer discretes.

KEY TECHNOLOGIES	DEVELOPMENT STATUS
Two-axis Gas-bearing gyros	Scaled version of Minuteman G-6
Accelerometers	40-unit prototype production
Terminal Descent and Landing Radar	Surveyor/LEM technology
Altitude Marking Radar	Electronics standard; antenna requires development

POWER AND PYROTECHNICS SUBSYSTEMS

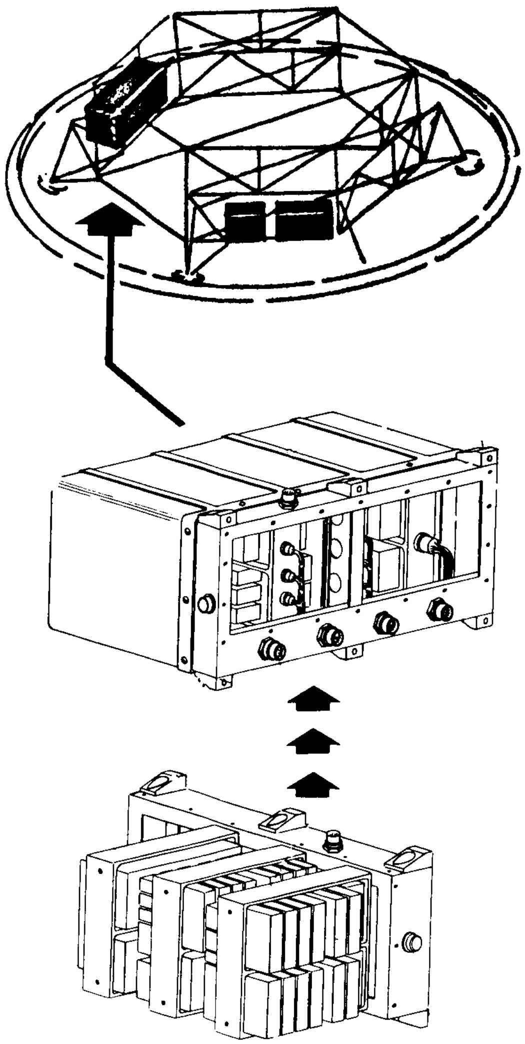


Key Features:

1) Silver-zinc batteries for 1973
2) Redundant feeders for critical loads
3) Complete redundancy in pyrotechnic subsystem--source through load
4) Isolated single point ground
5) Multiple batteries--cooperative multichannel redundancy

KEY TECHNOLOGY	DEVELOPMENT STATUS
Ag-Zn Batteries	New development required--long lead item Heat sterilizable battery technology--Electric Storage Battery Company--JPL contract Sterile assembly of batteries--Martin Marietta; NASA/LRC Contract NAS 1-7656

COMMAND AND SEQUENCING



Key Features:

1) Completely automated.
2) Remotely reprogrammable.
3) Discrete and quantitive outputs.
4) Self-test and complete memory read-out.
5) Time dependent outputs--functional redundancy.
6) Command decoding--cooperative multichannel redundancy.
7) Command parity check error detection.

KEY TECHNOLOGY	DEVELOPMENT STATUS
Plated Wire Memory	Proven Sterilizability

ALTERNATIVE CONFIGURATIONS

ALTERNATIVE CONFIGURATIONS

Two strong alternatives to the preferred configuration were developed: the first incorporating a different approach to the touchdown system, and the second a different power source for the Surface Laboratory.

Ring Touchdown System

The alternative touchdown system, Fig. 12, consists of a ring or infinite-leg system. Energy is absorbed at touchdown by crushable honeycomb in the six fixed struts. The landing ring also serves to attach the landing module to the aeroshell.

The advantage of this configuration is a larger stability envelope at landing than the legged configuration (see Fig. 13). Its disadvantage is an 80-pound weight penalty.

Inasmuch as the legged configuration is stable in the worst case condition of:

Vertical velocity = 25 fps

Horizontal velocity = 10 fps

Surface slope = 34 degrees

and the guidance concept is capable of providing landing conditions of:

Vertical velocity = 18 ± 5 fps

Horizontal velocity = 0 ± 5 fps

the legged configuration was selected as the preferred design.

An off-shoot of this approach was also considered in an effort to reduce the touchdown system weight. This involves substitution of an inflatable toroid for the metallic landing ring described above. This approach would, in fact, reduce touchdown system weight to the level of

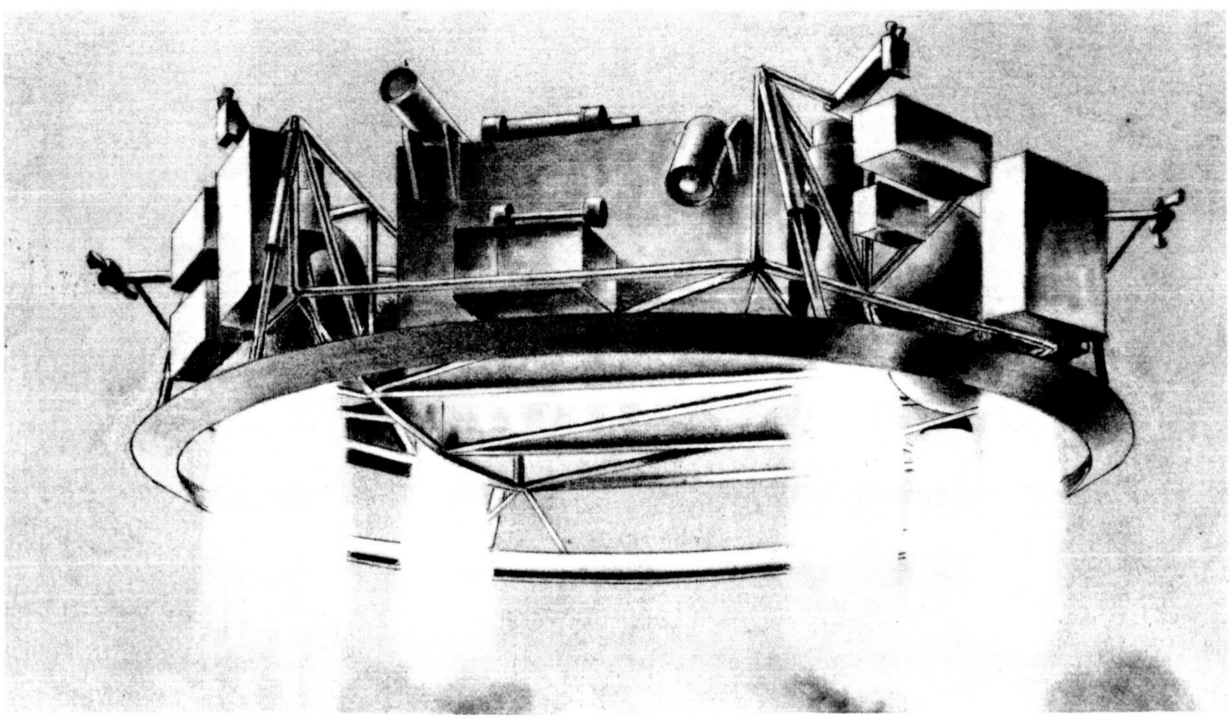


Fig. 12. Ring Lander Configuration

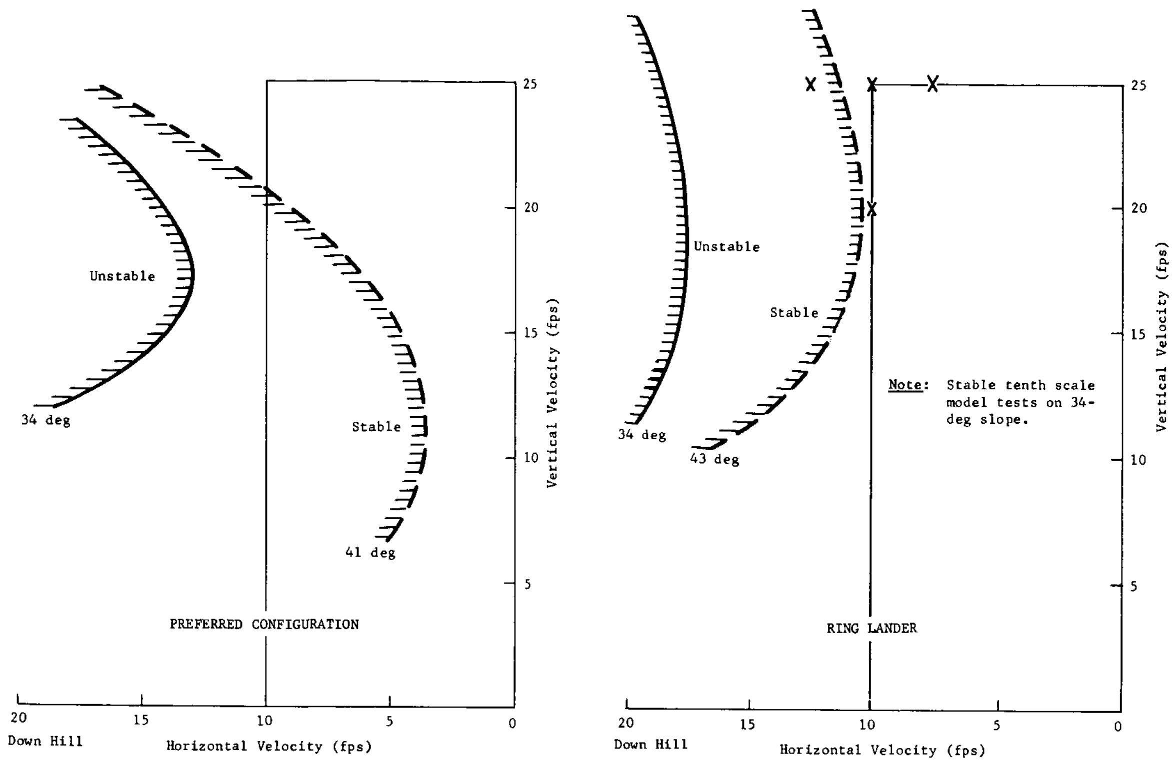


Fig. 13. Stability Envelopes for the Preferred Configuration and the Ring Lander Alternative

the four-legged configuration. However, sufficient attention has not been given to the question of inflation and sterilizability of the landing bag or to the analysis of landing conditions to warrant recommendation of this approach.

RTG Surface Laboratory

Considerations for extending the life of the Surface Laboratory beyond 50 hours led us to examining other primary power sources. Fuel cells were dismissed as too heavy and too complex. Solar-cell and RTG-powered systems are reported in Volumes III and VII, respectively. Under the conditions of surface winds and dust prescribed for the study,* the ability of the solar cells to increase the useful life of the Surface Laboratory was doubtful; hence, an RTG configuration was studied at length.

Two 83-watt (e) plutonium 238 RTG's were attached to the fixed Surface Laboratory (Fig. 14) to extend its useful lifetime to two years. The design is based on silicon-germanium hot juncture elements operated at 1250° F. The shape of the RTG is dictated by the safety concept of intact entry and impact from all failures while the particular location is dictated by thermal considerations. Nickel-cadmium batteries are used with the RTG, rather than the silver-zinc cells, because of their recharging cycle life.

Incorporation of the RTG increases the Flight Capsule system weight from 4980 pounds to 5286 pounds, increases program costs by between $60 and 90 million, and extends the Surface Laboratory life from 50 hours to 2 years. If the weight penalty and cost could be borne, this would be the preferred configuration and would lead smoothly into the four RTG mobile Surface Laboratories for later missions.

*"1973 Voyager Capsule System Constraints and Requirements Document," PD 606-4, Revision 2, 12 June 1967.

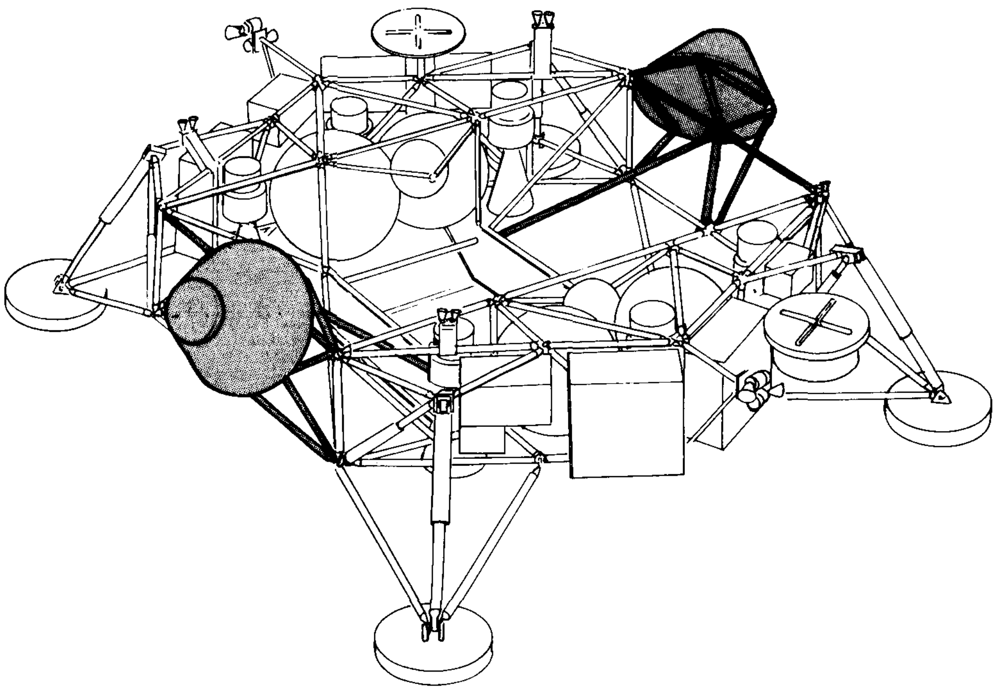


Fig. 14. RTG-Powered Surface Laboratory

II. UNIQUE TECHNICAL REQUIREMENTS

By the very nature of its mission, the Voyager Capsule Bus development program will require thorough application of existing technology in all disciplines involved and, in many instances, the extension of this knowledge to meet the program's unique requirements.

We have singled out for further discussion three critical requirements: sterilization, because this is its first application to quarantine of a planet; reliability, ever-present as a requirement and of paramount importance to mission success; and science experiment integration, because it represents a complex interface and potential schedule problems. This is not to say that we minimize the criticality of such areas as vehicle and system design, performance in the terminal descent and landing phases, long-lead items, and the need for maximum reliable data return--the latter, of course, being the ultimate goal of the program, and thereby commanding priority attention.

STERILIZATION

Martin Marietta applied a comprehensive technology base and a management emphasis to ensure full recognition of sterili-

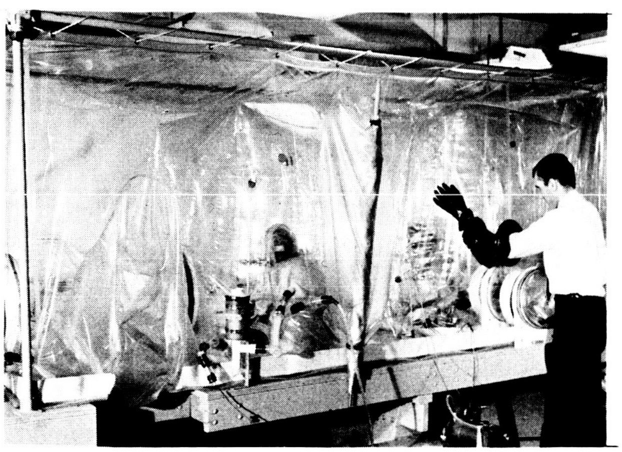


Fig. 15. Sterile Replacement of an Electronic Component through a Highly Contaminated Environment (Outer Bag) to a Sterile Environment (Inner Bag). NASA/Hdqs. Contract NASW 1407.

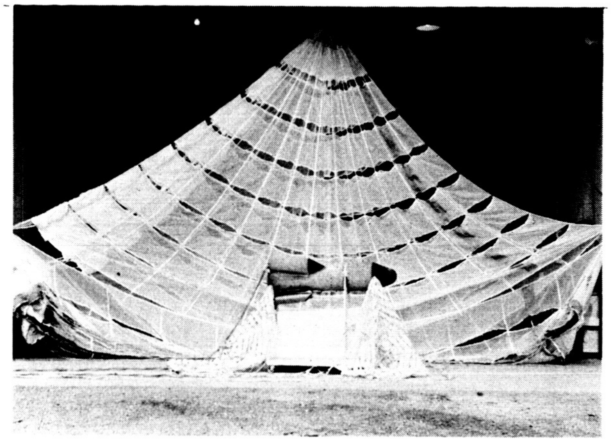


Fig. 16. Sterilized Parachute Used in "Planetary Entry Parachute Program." NASA/LRC Contract NAS 1-6703.

zation in the Phase B study. Phase B definition and tentative resolution of typical problems are summarized in Table 3. Exploration of new concepts that offer potential reduction of the effects of the sterilization requirements on reliability, cost, and schedules is continuing. Our total sterilization program has established the ability to provide technical direction to our subcontractors and to perform the integrated sterilization of the Capsule Bus System.

Technology

Sterilization criteria for the Capsule Bus System have resulted in the requirement for compatibility with ethylene oxide and dry heat, as well as the requirement for a vehicle capable of certification of microbiological burden accumulated during assembly and sterility protection from terminal sterilization through touchdown. The problems resulting from these new conditions have ranged from the choice of suitable parts and materials to the interaction of subsystems in the design of the Capsule Bus System. Sterilization inputs to the design of the preferred Capsule Bus configuration are backed by contractual and corporation-funded efforts by Martin Marietta and our subcontractors.

TABLE 3. STERILIZATION ACTIVITIES IN PHASE B

Impact/Problem Identified	Resolution/Approach
Propulsion	
1. Heat sterilization effects on propellants	1. Eliminate solids, cryogenics and inhibited red fuming nitric acid. Use monopropellant hydrazine.
2. Sensitivity of hydrazine to metal oxide contamination at sterilization temperatures	2. Eliminate steel from fuel storage system; develop and test cleaning processes; add heat sterilization for loaded fuel tanks; provide emergency vent valve on the fuel tanks.
3. Fuel tank pressure rise due to expansion of the gas and liquid, and increased vapor pressure	3. Increase design margin for propellant tanks; provide separate storage for the pressurizing gas.
Guidance and Control	
1. Nonreversible viscosity changes in flotation fluid floated gyros during heat sterilization	1. Redesign floated gyros; sterilization testing of free-floating gyro design
Structure and Mechanics	
1. Need for a biologically secure sterilization canister	1. Design of reliable hermetic seal, biologically secure vents, reliable jettison system
2. Tank pressure rise during heat sterilization of loaded propulsion subsystem	2. Design of structurally strengthened tankage
Telecommunications and Power	
1. Requirement for heat sterilizable batteries	1. Initial design to anticipated sterilizable silver-zinc batteries, study of sterilizable silver-cadmium and bipolar nickel batteries
2. Post-terminal sterilization umbilical checkout of subsystem	2. Incorporation of a subsystem checkout multiplexer
Test and Launch Operations	
1. Requirement for ethylene oxide and dry heat environmental testing	1. Integrated test/sterilization flow to incorporate environmental test and biocontrol factors
2. Requirement for biological control throughout assembly-to-launch sequence	2. Development of complete control and monitoring programs for class 100 and 100,000 assembly area. Bioassay and control will be maintained throughout manufacturing and test sequence until launch

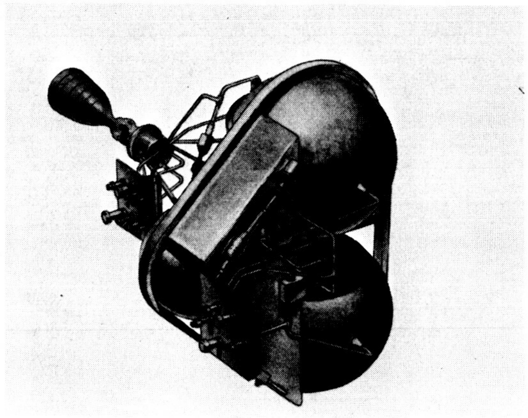


Fig. 17. Totally Sterilizable Liquid Module has been Designed. Manufacture and Test to Follow Under JPL Contract 951079.

Contractual efforts by Martin Marietta include:

JPL Contract 951709--Sterilizable Liquid Propulsion System (10/67 to 6/68).

NASA Hdqs. Contract NASW 1407--Feasibility of Gnotobiotic Techniques for Sterile Insertion (6/66 to 10/66).

NASA Hdqs. Contract NASW 1621--Design of Practical Sterile Insertion Techniques (5/67 to 10/67).

NASA/MSFC Contract 21122--Microbiological Aspects of Sterile Insertion (6/67 to 1/68).

JPL Contract 952028--Biological Contamination Mathematical Model (8/67 to 4/68).

NASA/LRC Contract NAS 1-7656--Sterile Assembly of Batteries (negotiated but not definitized).

NASA/LRC Contract NAS 1-6703--Planetary Entry Parachute Program (10/66 to 1/68).

Corporation-funded research and development studies by Martin Marietta include:

Radiation Sterilization Study

Ethylene Oxide and Heat Compatibility of Electronic Parts, Potting Compounds, Thermal Control and Propulsion Equipment

Ethylene Oxide Compatibility of Magnetic Tape

Heat Compatibility of Solder

Transtage Bioload Study

Facilities Biomonitoring Study

Sterile Isolator and Checkout Study

Isolator Versus Laminar Flow Versus Open Assembly Study

Technology Feasibility Spacecraft Program

Contractual efforts by Martin Marietta subcontractors include:

JPL Contract 951556 with NAA Autonetics--Effects of Sterilization on Spacecraft Polymeric Materials

JPL Contract 95085 with RCA Astro-Electronics Division--Development of a Sterilizable Ruggedized Vidicon

JPL Contract 951983 with Hughes Aircraft Space Systems Division--Phase III Investigation of Ethylene Oxide Effect on Component Parts (7/67--Study in Progress)

JPL Contract 951663 with Hughes Aircraft Space Systems Division--Test Program to Study Thermal Sterilization Effects on Connector Cup Solder Joints and Determine Operation Parameters for Application of Solders (9/66 to 6/67)

JPL Contract 951003 with Hughes Aircraft Space Systems Division--Effects of Heat and Ethylene Oxide on Materials (10/64 to 4/66)

NASA Contract NAS 8-5499 with Hughes Aircraft Space Systems Division--Development of Improved Heat Sterilizable Potting Compounds (7/63 to 9/66)

JPL Contract 901069 with Hughes Aircraft Space Systems Division--Sterilization Procedures on Electrical Properties of Solderable and Weldable Joints for Space Use (3/65 to 10/65)

New Concepts

The Phase B study was limited to a prescribed set of concepts and sterilization constraints. Recognizing the critical effect of the sterilization requirement on mission reliability, schedule, and cost of the Voyager program, Martin Marietta has introduced a new-concepts program as part of our corporation-funded efforts. This activity is exploring alternative means of complying with the basic planetary quarantine requirements. Alternatives under investigation and planned include:

1) Methods of alleviating the reliability and schedule effects of failures after terminal heat sterilization

2) New bio-assay techniques with shorter processing time, less cost, and lower variability

3) Pretreatment and preconditioning of hardware to minimize contamination

4) Sterile insertion methods including extremely sensitive biological contamination indicators

5) Combined physical and chemical agents with positive surface sterilization effect compatible with Voyager hardware

6) Novel assembly and packaging practices for improved biological security.

Management

Responsibility for sterilization in Phase B and all subsequent phases has been assigned to the Sterilization Assurance Manager reporting directly to the Voyager Program Director. This assignment provides a single focal point for sterilization policy, criteria, requirements, indoctrination, consultation, and technical decisions on the Voyager program. The Sterilization Assurance Manager is also responsible for monitoring corporation-funded research and development activities in sterilization to ensure an automatic feed-back of R&D data into Voyager applications. His membership on the Capsule Piece Parts, Materials, and Processes Board ensures proper consideration of the effects of sterilization on the reliability of potential Voyager hardware.

Fig. 18. Electronic Assembly in a Sterile Isolator to Determine Biological Load for Comparison with other Techniques.

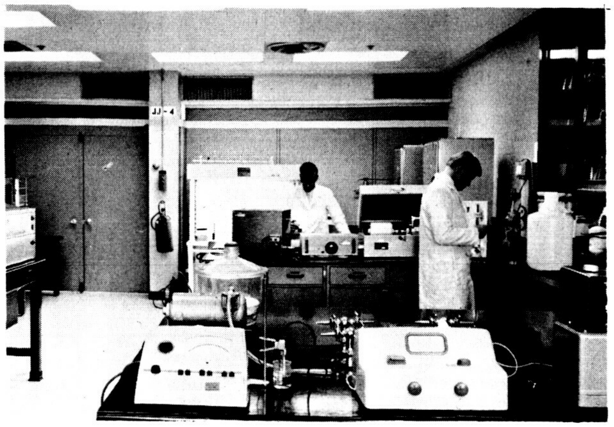


Fig. 19. Martin Marietta Space Biology Laboratory.

A Sterilization Control Committee was also established at the start of Phase B to ensure a coordinated uniform sterilization program by Martin Marietta and its major subcontractors. The Sterilization Assurance Manager is chairman of this committee; each subcontractor is represented by the individual responsible for overall sterilization planning and operation within his Voyager organization.

The sterilization staff is composed of individuals with extensive background in the basic program disciplines affected by sterilization: Reliability, Engineering, Test, Manufacturing, Quality, Materials, Procurement, and Space Biology. This staff ensures that sterilization is considered in the trade studies, design configuration, integrated assembly and test flows, and the plans described in other volumes of this Phase B report.

The interrelationships of the sterilization staff, industrial consultants, scientific consultants, sterilization control committee, subcontractors, and NASA are shown in Fig. 20.

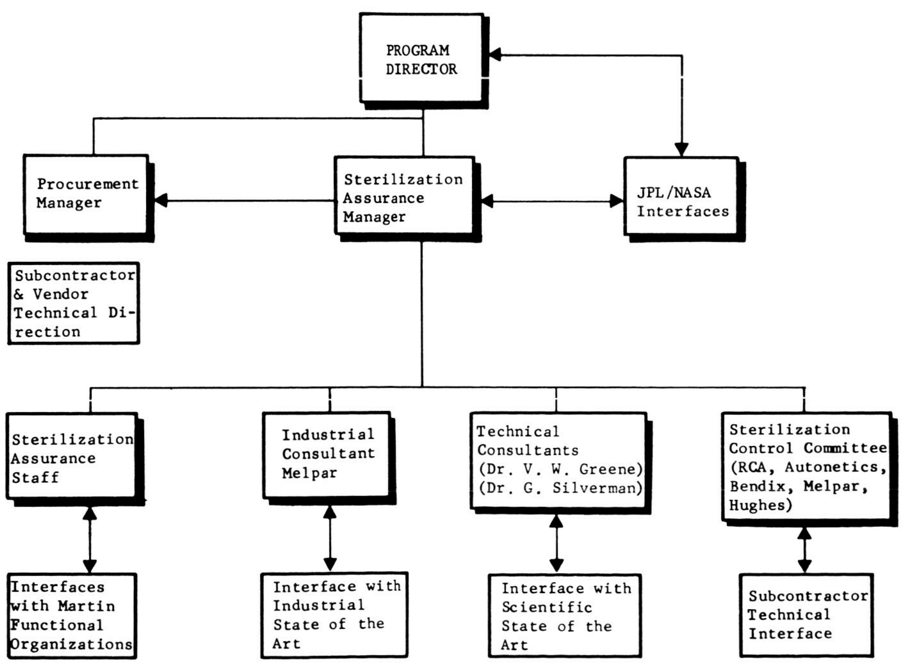


Fig. 20. Sterilization Organizational Interfaces.

RELIABILITY

On the Voyager Flight Capsule, special reliability requirements are imposed by the planetary quarantine, the once-every-two-years launch opportunity, the long space journey, and landing and operation in an unknown environment. Success of the Voyager mission depends on the degree to which the systems designs meet these requirements. On a more detailed level, mission success also depends on the reliability of some 100,000 piece parts, 200 different materials, and 600 processes--each of which can cause, or at least contribute to, a failure.

Technical Approach

The starting point for our reliability activities is selection of proved techniques from successful programs that have had similar reliability requirements. Martin Marietta and its major subcontractors have had direct participation in applicable programs; e.g., Gemini Launch Vehicle, the Tiros weather satellites, and Surveyor--programs that reinforce the technology from Mariner and existing development programs. Reliability activities that have proved to be critically important in these and other space programs in which we have participated are summarized in Table 4 for application to Voyager. Activities that we consider important in fulfilling the more stringent requirements of Voyager are summarized in Table 5.

The following contractual and Corporation-funded interplanetary studies are typical of reliability techniques that we are giving special emphasis at the present time.

Configuration control, using electronic data processing, applied to flight and ground hardware; manufacturing and test processes; test specifications, procedures, and tools.

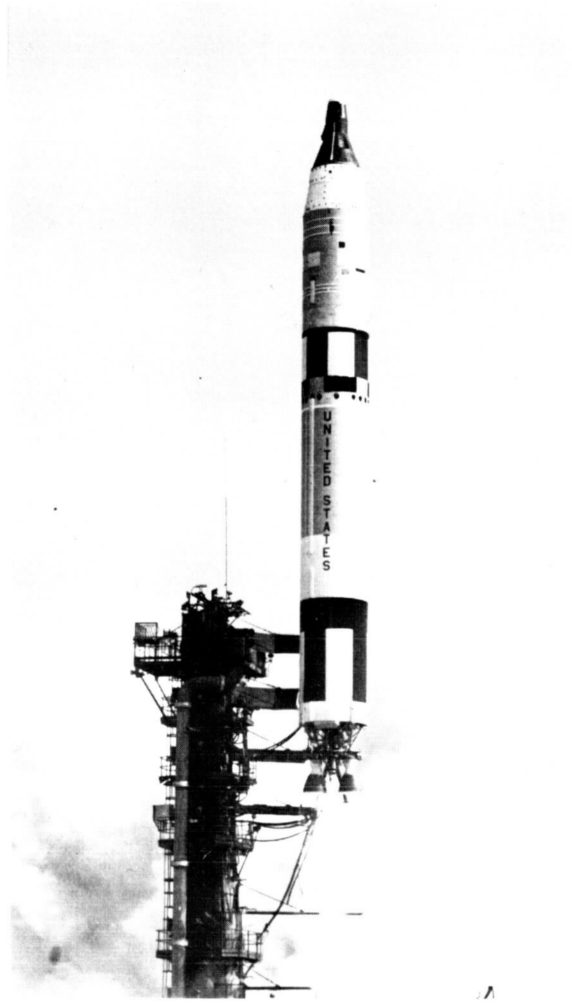


Fig. 21. The Gemini Launch Vehicle, which had Twelve Successes in Twelve Tries. Unique Critical Components Program Established Rigid Controls on Manufacturing, Configuration, Handling, and Test in Martin Marietta and 32 Subcontractor Organizations. (NASA/AFSSD).

Failure mode/effects and criticality analysis, with focus on wear-out and sterilization-induced modes of failure, functional rather than block redundancy; and referencing each failure mode to a specific process control, inspection, or test to detect or prevent failures.

Common use of piece parts by Martin Marietta and its subcontractors, with specific assignment of qualification and testing responsibility.

TABLE 4. RELIABILITY ACTIVITIES ON PRESENT AND PAST MARTIN MARIETTA/NASA PROGRAMS

ANALYSIS	HARDWARE DESIGN AND DEVELOPMENT	HARDWARE FABRICATION, TEST AND USE
Failure mode/effects analysis: Identify all failure modes and effects on each mission phase.	Performance and environmental stress requirements documented quantitatively for each mission phase.	Configuration control from total system to piece-part level on hardware processes, test specifications and procedures, test tools and airborne system functional test set.
Failure mode/effects analysis verified experimentally on configuration controlled test set.	Qualification test stress margins high enough to guarantee: (1) design reliability, and (2) no damage from environmental acceptance tests.	Failure reporting and corrective action system: Anomalies reportable by all activities, closed only with reliability approval; changes processed through complete configuration control system.
Configuration controls imposed on test sets.		Flight hardware with unexplained anomaly never allowed to fly.
Reliability model that allocates total system requirements to specific functions and hardware elements for each mission phase.	Piece parts and materials: Imposed and documented, consistent de-rating techniques.	Incremental inspection documented and implemented at all levels from piece part to total system.
		All in-house and subcontractor acceptance procedures documented by Quality Engineering.
	Closed loop failure-reporting and corrective action system starting with qualification test: No unexplained or random failures.	Contamination levels controlled and monitored in-house and at subcontractors.
	Interface compatibilities verified experimentally on configuration controlled airborne system functional test set.	Complete folders each flight component: Total history including environmental acceptance test duration.
PERSONNEL TRAINING AND DISCIPLINE	Certification and performance examinations for each person in program by independent agency. Individual and crew certification for test crews. Test procedures carried out by test engineers with each engineer's operations monitored by independent agency (Quality Assurance).	

TABLE 5. RELIABILITY ACTIVITIES ADDED OR MODIFIED FOR VOYAGER CAPSULE BUS PROGRAM

ANALYSIS	HARDWARE DESIGN AND DEVELOPMENT	FABRICATION, TEST AND USE
Failure mode/effects criticality analysis with special emphasis on wear-out and sterilization-induced failure modes: Fatigue, abrasion, corrosion, and chemical degradation, especially from out-gassing products.	Failure reporting and corrective action system implemented in development tests: Eliminate high risk items, reduce risk of not completing qualification tests in time for once-every-two-years launch period. Tolerance Control: Tolerance allocation to each component and worst case analysis (verified experimentally) on tolerance build-up at each system level to eliminate wear-out modes caused by poor fits and misalignment. Component packaging problems caused by thermal sterilization cycle: Analysis and tests to allow for permanent material degradation: and permanent mechanical damage caused by temporary material-property degradation, accompanied by thermal stress. Heat path control to eliminate local hot spots (verified experimentally).	Processes limited to those approved by CPMP board. Piece parts and materials subjected to acceptance tests and screening requirements common for all team members. Environmental acceptance test includes thermal cycling.
Failure mode/effects diagram references specific documents: Test spec./procedure, process control, and/or inspections which detect or prevent failure. Each failure mode identified. Redundancy: Emphasize functional over block redundancy. All previous in-space failures specifically accounted for in FMECA's.	Established Capsule Parts, Materials, and Process board (CPMP) to implement and/or control: 1. Capsule system approved parts and materials list. Use mandatory, including subcontractors. 2. Need for new part types determined by tradeoff study and design review with CPMP board approval. 3. Choice of new part on list: Past performance, part material, mechanical design/configuration, and potential failure mechanisms. 4. Part type, lot, and individual part specifications and traceability requirements. 5. Common usage and procurement of parts for Martin Marietta and subcontractors. 6. Maximum use of parts previously qualified by space performance and sterilization compatibility plus NASA/JPL test data. 7. Elevated stress as well as rated stress life tests. Eliminate high risk items early. Tests to failure or pre-determined margins of development hardware for selected critical items to determine absence of or verify failure modes.	Complete pre-qualification development system subjected to environmental stresses to identify total assembly problems early. Flight acceptance testing includes heat sterilization and ethylene oxide decontamination at component/subassembly level prior to terminal heat sterilization.
PERSONNEL TRAINING AND DISCIPLINE	Test Crews: Individual and crew certification as in earlier program; crew assigned one capsule during whole test and launch cycle.	

Development testing at all levels of assembly to evaluate the component packaging problems resulting from sterilization requirements; e.g., thermal stresses generated during heat sterilization and degradation of materials caused by high temperatures and ethylene oxide decontamination. (Test data show that the solder most widely used is unacceptable for Voyager.)

Sterilization testing of assemblies such as a sequencer, squib firing circuit, solid-state transmitter, and gas-bearing gyroscope, to provide design information for sterilizable assemblies.

Tolerance control which includes tolerance allocations and experimental verification of tolerance buildup at each system level to eliminate wear-out failure modes.

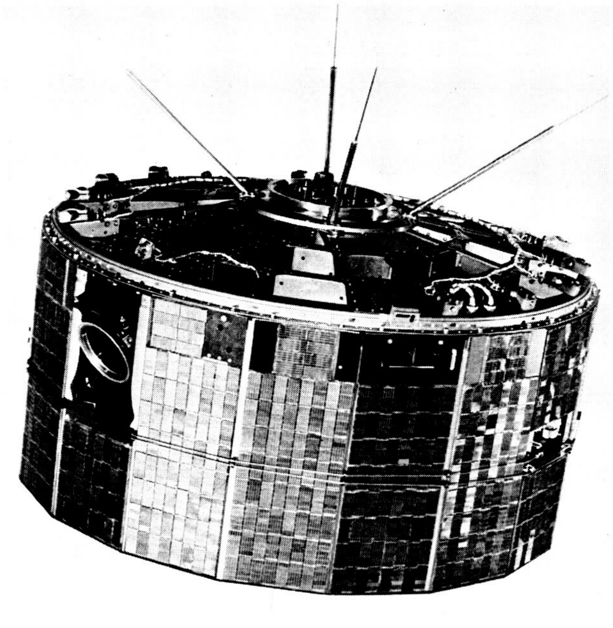


Fig. 22. Like Voyager, the Tiros is a Prolonged-Mission System; Three of These Weather Satellites have been Operating for Three Years Each. (NASA/RCA).

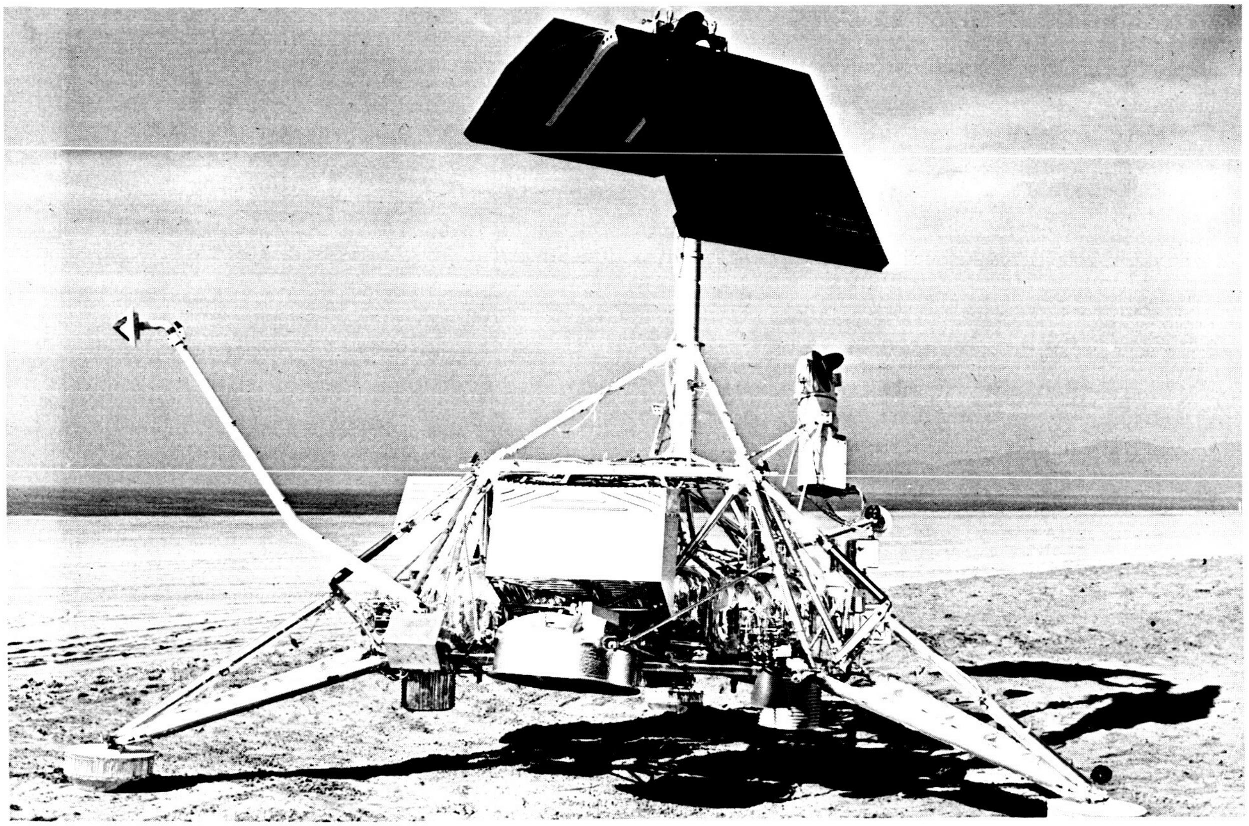


Fig. 23. Soft Lunar Landings by Surveyor Provide Valuable Background for Voyager. (NASA/ Hughes).

Refinement of closed-loop corrective action systems.

Basic to all these reliability techniques is a thorough understanding of past failures in space, their causes, and corrective actions to ensure success. Accordingly, we are studying all available spacecraft failure data as background for reliable design, production of quality parts, and effective application of procedures.

Management Approach

Although we insist that reliability is "everybody's concern," the keystone of our program is clear-cut centralization of responsibility. On the system level, this is implemented by the Reliability Assurance Manager (reporting to the Program Director), with responsibility for both Martin Marietta and subcontractor reliability activities. On the subassembly and major component level, we employ product integrity engineers who have the charter to control the integrity of "their" product throughout its entire history from design drawing to approval for flight. The Reliability Assurance Manager will provide leadership for control of detailed piece parts through the Capsule Piece Parts, Materials, and Processes Board (CPMP), with representation from all major subcontractors. Neither a rubber-stamp nor an advisory agency, this board has significant responsibilities as defined in Table 5.

It is imperative that subcontractor and other suppliers be brought on board the reliability program . . . that their efforts be consistent with that of the prime contractor. Typical techniques for ensuring their effective participation include: (1) a direct, "short-line," reporting relationship to the Martin Marietta Program Director; (2) representation on the CPMP Board for control of piece parts, materials and processes; and (3) assignment of reliability goals, tolerances, allocations in the same manner as for Corporation-funded operations.

We believe that rigorous management control of the existing, modified, and new techniques summarized in Tables 4 and 5 will result in a reliable Voyager Capsule Bus System and a high degree of confidence in ultimate mission success.

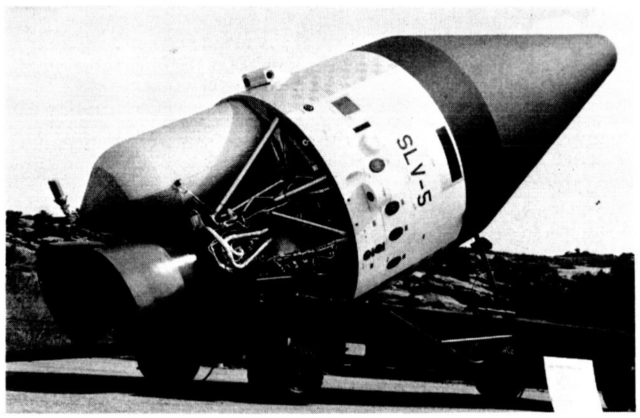


Fig. 24. Titan III Transtage Spacecraft Exhibited High Manufacturing Quality (In 1966, 288,000 Soldered and Welded Connections Were Made with Only 50 Joints Being Found Defective in Quality Inspection and One Latent Defect in Later Stages of Test).

SCIENCE EXPERIMENT SELECTION AND INTEGRATION

Through Phases B and C of this program, the technology and design concept of the Voyager Capsule Bus System is crystallizing. The selection of experiments, particularly those relating to the primary mission objective--the search for extraterrestial life--is now in its formative stages. The "search for life" goal is diffused by a lack of consensus within the scientific community as to what constitutes "life" or what criteria would qualify an experiment, or a set of experiments, to best meet the "search for life" objective. The spectrum of approaches ranges from one that seeks chemical background information of biological interest to one with a full complement of direct life--detection experiments with chemical and physical assays accommodated on a space-available basis.

Our design approach is cognizant of these unresolved problems by providing flexibility in power, data systems, telemetry, and communications to incorporate widely varying experiments. But a potential critical problem arises, not from the choice itself, but from the time path required to make the choice and provide experiments and, particularly, adequate instrumentation. The latter must be developed through the long-life piece parts and sterilization requirements cycles to meet the inviolate launch opportunity.

Experiment problems such as these are under review by NASA with the help of leading biologists, the Space Science

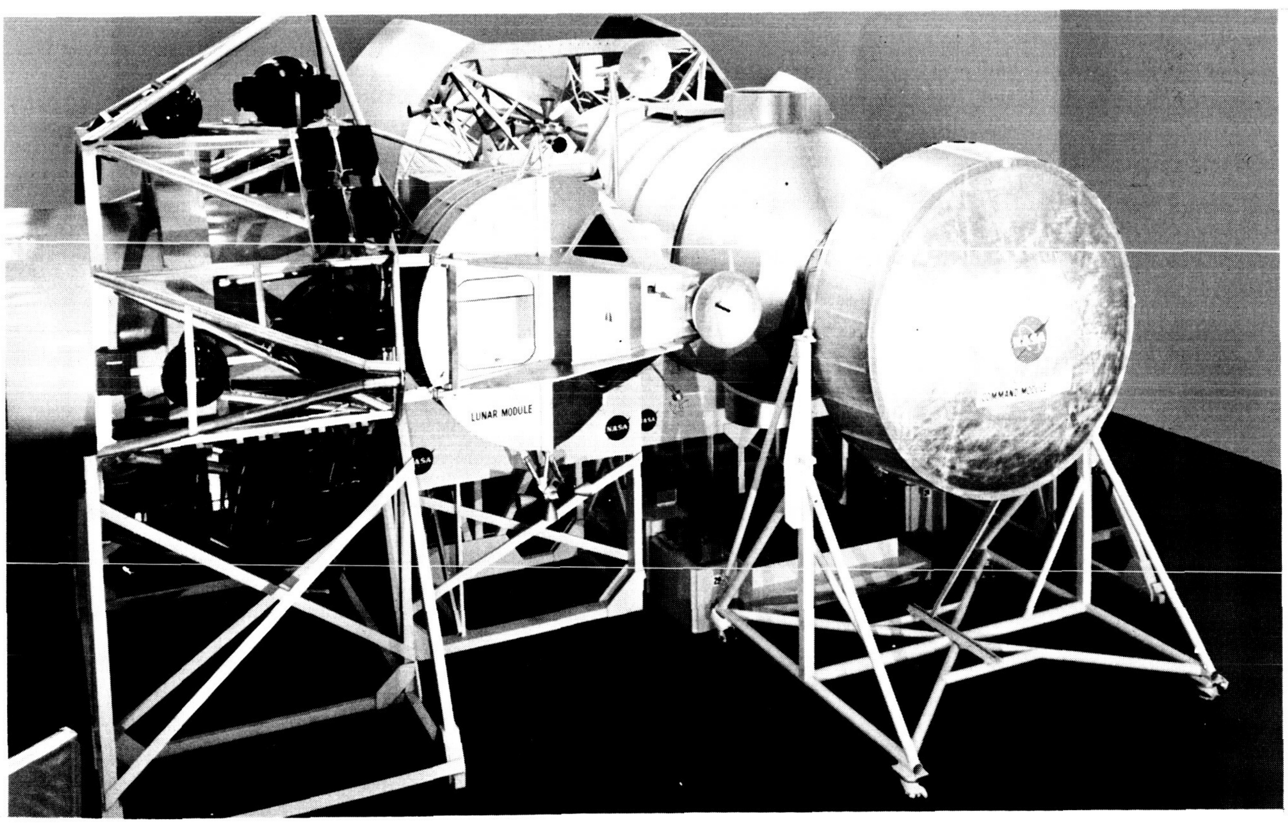


Fig. 25. Major Elements of Early Version of Apollo Applications Program (AAP) Cluster Configuration. Martin Marietta Is Responsible for Payload Integration. (NASA/MSFC, MSC, and KSC).

Board, and the Planetary Missions Board, seeking to establish consistent policy. The formal NASA/OSSA announcement of opportunity to participate in the Voyager 1973 mission has just been issued to the scientific community. The experiment choice is time-consuming because after receiving suggestions it is necessary to integrate a group of experiments to best meet the mission objective.

It is important, therefore, to consider new approaches to ensure meeting Voyager implementation schedules with a full complement of instruments available for the launch window. A number of approaches are suggested for serious consideration:

1) Publish to the scientific community a simplified, hard decision-tree structure and schedules for choice of experiments, integration of experiment groups, and the requirements of the Voyager Implementation Plan.

2) Develop a reserve complement of experiments on the same time schedule to be substituted for those that, for any reason, appear to be falling behind the very tight implementation plan. This approach also provides a degree of flexibility as knowledge of Mars increases.

3) Initiate Phase C design of readily definable experiments, such as entry science and physical properties measurement from the Surface Laboratory System, before final choice of grouped experiments.

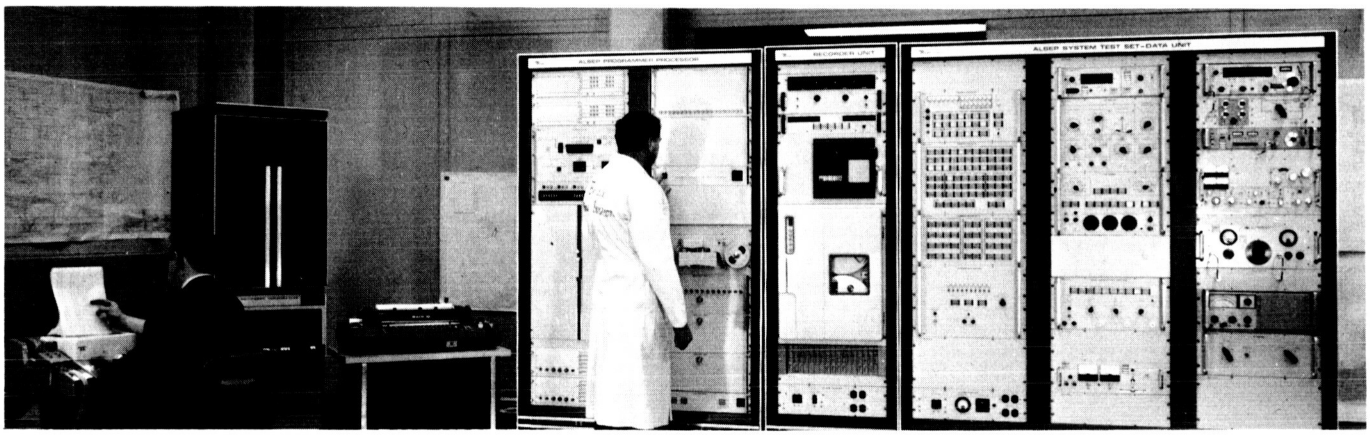


Fig. 26. Test Set for Apollo Lunar Surface Experiment Package (ALSEP). The ALSEP Is an Autonomous Automatic System to Collect and Transmit Apollo Program Scientific Data from the Lunar Surface. The Scientific Areas Include Geology, Geophysics, Geochemistry and Particles and Fields. (NASA/MSC/Bendix.)

III. INTEGRATED TEST PLAN

The primary objectives of the Voyager Flight Capsule test program are 1) proof of all functions in a simulated mission environment; 2) early identification of design problems and weaknesses.

To accomplish these objectives, the test philosophy is to start testing at the lowest possible level of assembly, and then evaluate empirically the effect of interactions caused by each successive assembly operation. The process proceeds from piece parts through subsystems to the complete system including simulated mission and planetary vehicle combined systems tests. This is done during the development phase to evaluate the design, during the qualification phase to demonstrate design maturity, during flight acceptance to verify hardware performance, and during launch site operations to verify flight readiness.

Development

Development tests are conducted at the component, subsystem, and system levels to evolve and verify design approaches through the demonstration of design feasibility, functional characteristics, fabrication and packaging techniques, environmental limitation, and design margin.

During the development phase, a number of models are used to evaluate design concepts and performance characteristics. These are listed in Table 6. Figure 27 summarizes the development test program for the Capsule Bus.

Qualification

Qualification tests are conducted at levels of assembly from component through Capsule Bus System, to demonstrate the design maturity of the configuration evolved from development. In addition, these tests establish design confidence through the performance of stress/time tests conducted as a part of formal qualification.

Table 7 indicates the test articles required to support qualification. The complete scope of qualification activity is shown in Fig. 28.

Flight Acceptance

Flight acceptance tests verify that the flight item is functionally identical in all respects to the qualified configuration, and that specifications are satisfied. Figure 29 shows the sequence of operations performed at Denver to assemble and accept the Flight Capsule. This sequence is based on considerations of biological control, facilities, manpower, transportation problems, schedule, and mission confidence.

Launch Site Operations

Launch site operations are those activities necessary to continue the verification and acceptance process at Kennedy Space Center in conjunction with the Surface Laboratory System, Spacecraft and launch vehicle. All launch site operations are diagrammed in Fig. 30. Observance of planetary quarantine constraints is emphasized during these operations.

Surface Laboratory and Entry Science Package

Tables 6 and 7 indicate the test articles required for development and qualification of the Surface Laboratory System and the Entry Science Package. The test operations performed on these systems are similar to those shown in Figs. 27 through 30.

TABLE 6. DEVELOPMENT TEST ARTICLES

Article	Quantities			Scale
	CBS	SLS	ESP	
Aerodynamic specimens	A/R			1/10
Aero specimens for parachute	A/R			1/10
Hard mockup	1	1	◇1	F/S
Propulsion development test model	1			F/S
Thermal insulation scale mockup	1	1	◇1	1/4
Aeroshell stress test model	6			3/8
Structures landing model	1			3/8
Guidance & control aircraft tests	A/R			F/S
Aerodynamic decelerator development model	3			F/S
Antenna test scale model	1	1	◇1	3/8
Thermal Control Model	1	1	◇1	F/S
Air bearing table	1			F/S
Captive firing model	1			F/S
Engineering Test Model	1	1	1	F/S

◇1 Indicates use of the Capsule Bus Test Article

A/R--As required

TABLE 7. QUALIFICATION TEST ARTICLES

Article	Quantities			Scale
	CBS	SLS	ESP	
Structures impact model	1	1		F/S
Structures Test Model	1	1		F/S
Aerodynamic deceleration qualification model	3			F/S
Descent performance test model	2			F/S
Proof Test Model	1	1	1	F/S

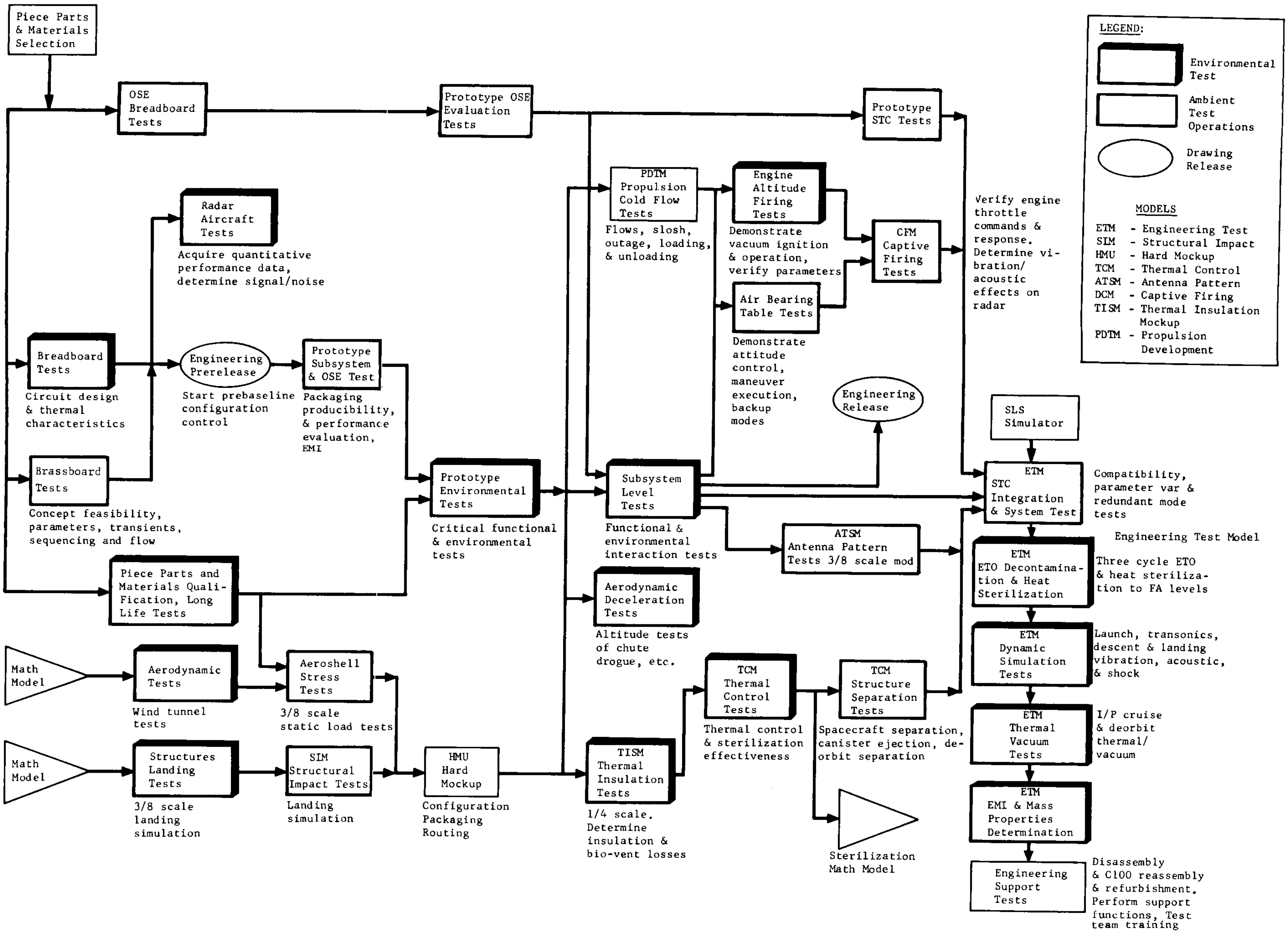


Fig. 27. Development Test Summary

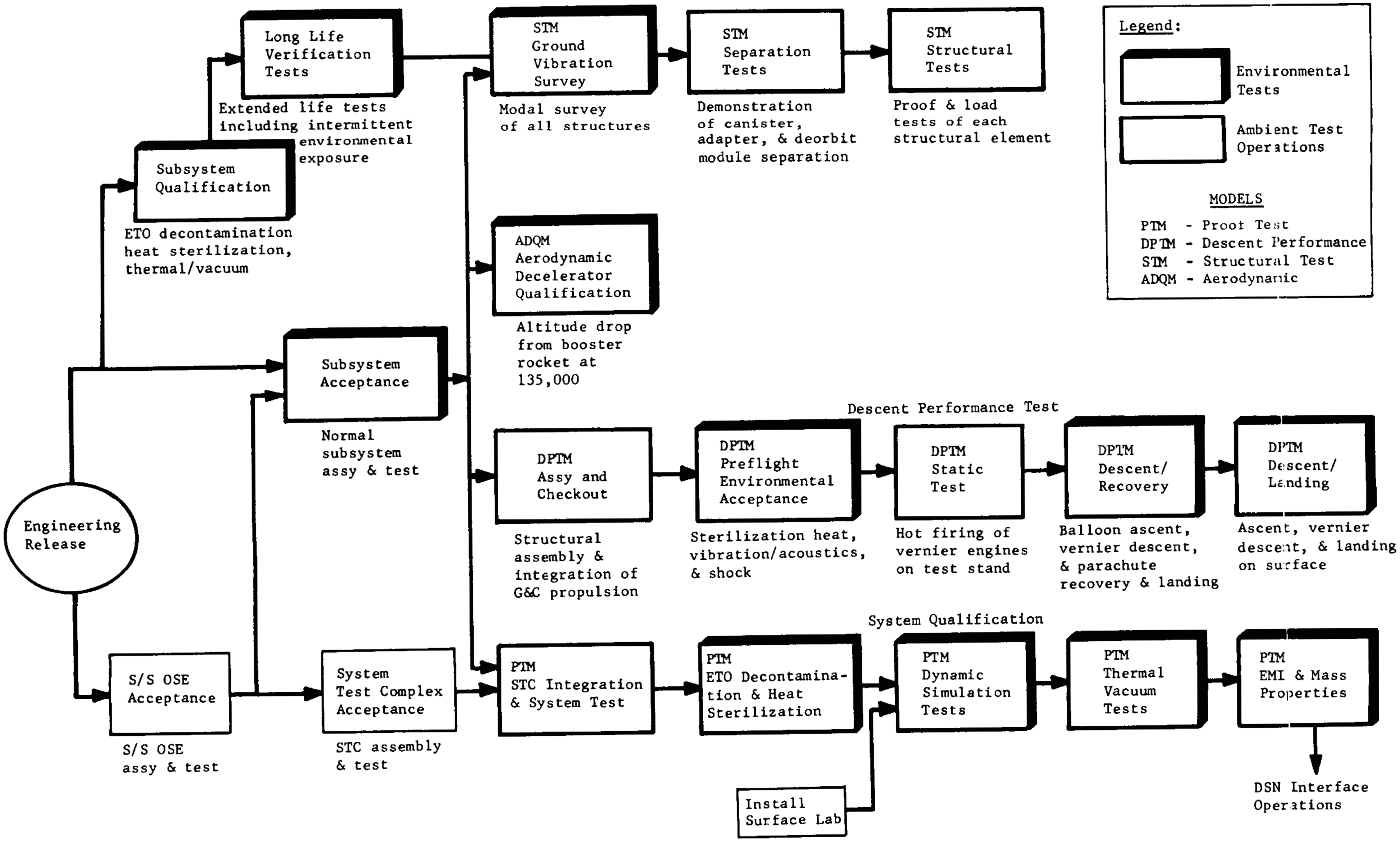


Fig. 28. Qualification Test Summary

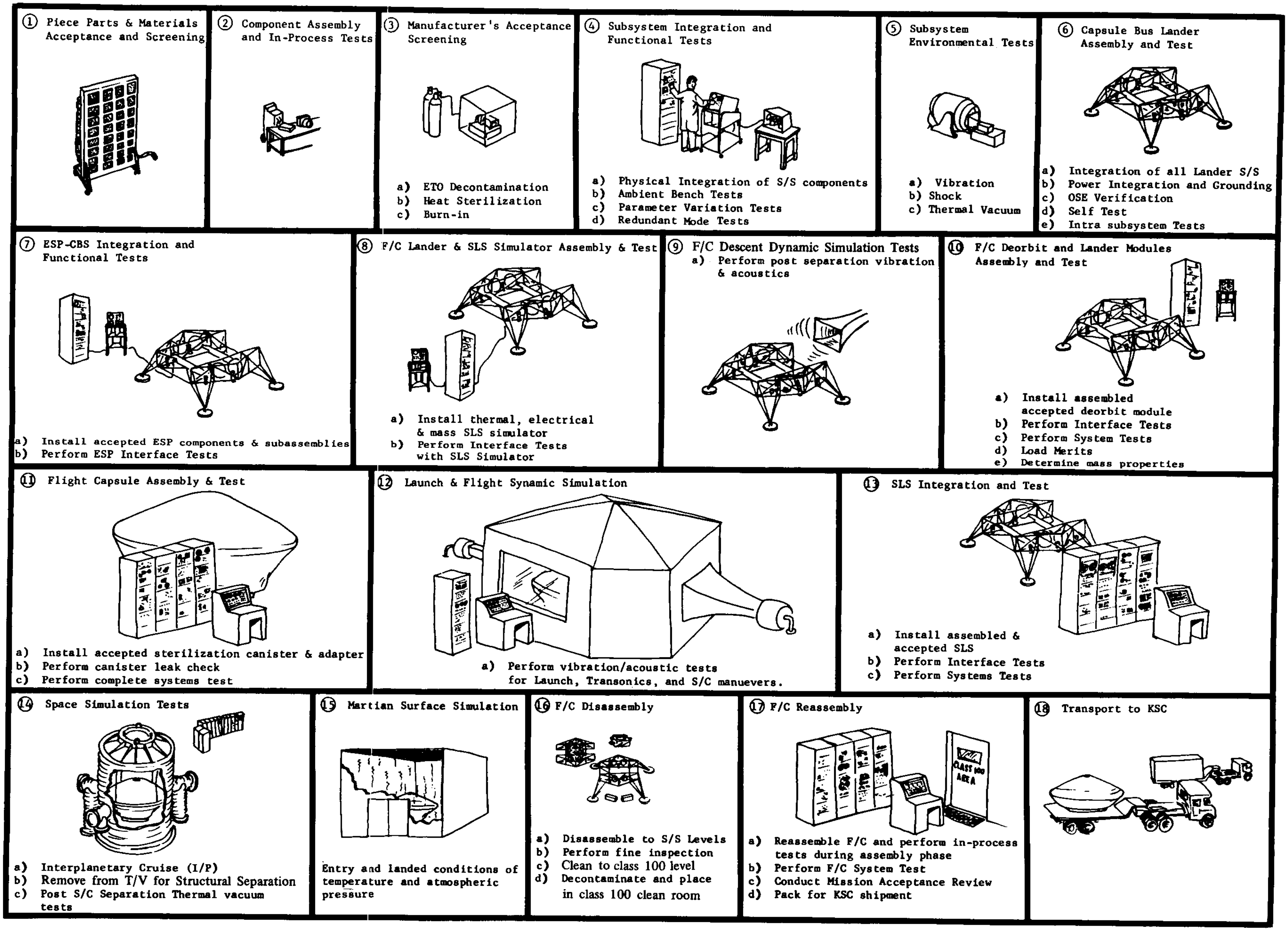


Fig. 29. Flight Capsule and Assembly, Denver Operation

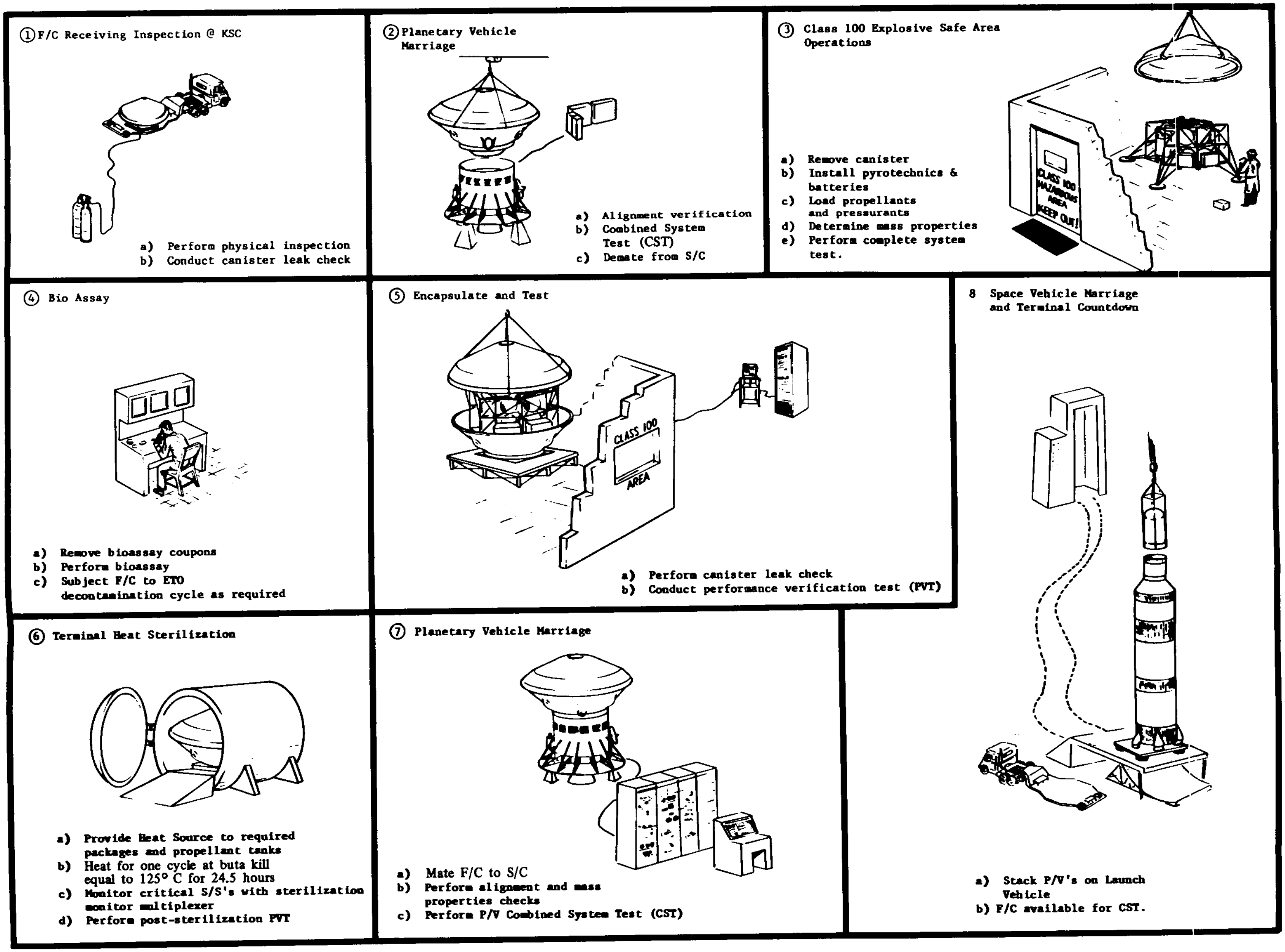


Fig. 30. Flight Capsule Launch Pad Operations, Kennedy Space Center

IV. IMPLEMENTATION PLAN

This section presents the highlights of the Implementation Plans, which are covered in Volumes II, III, and IV.

PROGRAM PLAN

The Master Schedule for the Voyager Capsule Bus System (Fig. 31) shows the major activities and milestones required to accomplish the program. Some of the significant milestones are:

Subsystem Preliminary Design Reviews completed by the end of Phase C (February 1969)

Final Subsystem Critical Design Reviews completed by November 1970

Start of System Level Space Simulation Test on the Engineering Test Model including use of a Surface Laboratory System Simulator in November 1970

Subsystem qualification completed in March 1971

Start Flight Capsule system level (Capsule Bus, Entry Package, and Surface Laboratory) qualification tests March 1971

System Qualification complete in December 1971

First Flight Article final assembly start October 1971

Flight Articles available: Entry Science Package November 1971 for installation in the Flight Capsule, Surface Laboratory System February 1972

First Flight Article acceptance complete in November 1972

Flight Ready in July 1973

Mars Landing, February - March 1974.

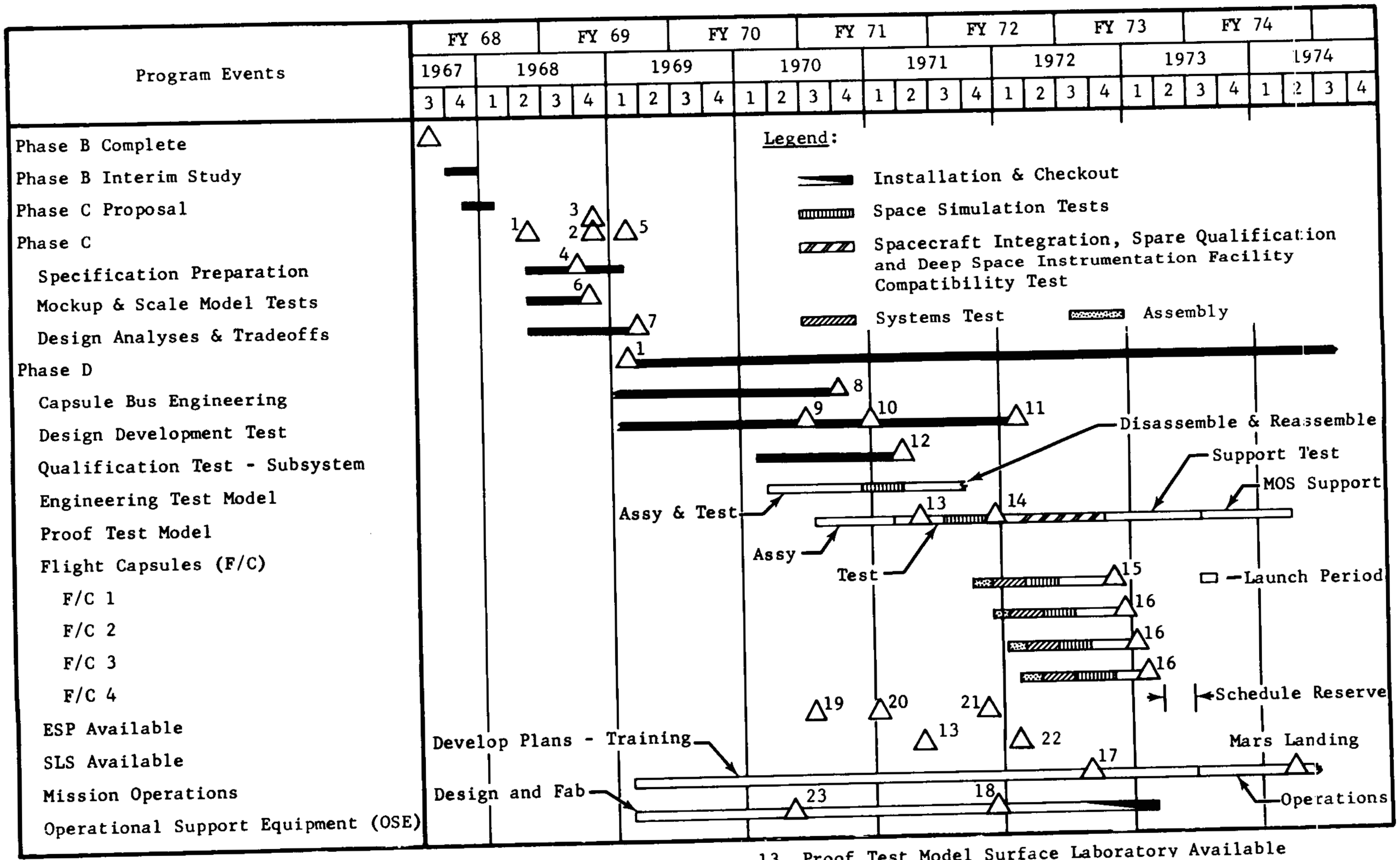
RATIONALE

During precontractual studies and in Phase B we have developed concepts that are the basis for the implementation plan. These concepts deal with the timing of the critical activities necessary to ensure meeting the program objectives. Some of these concepts are discussed below.

In examining the overall schedule requirements, consideration must be given to the availability of piece parts. The critical parts are those that must be qualified and accepted by the Capsule Parts, Materials, and Processes Board for addition to the approved parts list. Our master plan recognizes that some new parts will be identified late in Phase C and early in Phase D. Even in the case of parts identified in Phase D, the master schedule provides for 1600 hours of life testing before the start of Proof Test Model component build and 8000 hours of life testing before completion of Proof Test Model final assembly.

Early release and fabrication of the engineering test model from nonflight hardware is to begin in the first year of Phase D. The purpose is to provide the earliest possible system evaluation that will allow the identification of major systems problems at a time concurrent with the building and qualification testing of subsystems. Upon completion of system level tests with the Engineering Test Model it will be used as an early "pathfinder" model for checking out facilities, people, procedures, and equipment at the Kennedy Space Center. This provides an early evaluation of program interfaces and allows sufficient time for necessary modifications before delivery of the first Flight Capsule.

All subsystems will have completed qualification before the beginning of the Proof Test Model systems test except the thermal control subsystem, which can only be qualified with a complete system test.



1 Go-Ahead
2 Long-Lead Items Identification Complete
3 Preliminary Design Review Complete - End Items
4 End-Item Specifications Submitted
5 Component Specifications Submitted
6 Full Scale Mockup Complete
7 Detailed Configuration Selected
8 Final Critical Design Review
9 Ground Vibration Survey Test Complete
10 Static Test Complete
11 Descent Performance Test Complete
12 Subsystem Qualification Tests Complete
13 Proof Test Model Surface Laboratory Available
14 System Qualification Tests Complete
15 First Article Configuration Inspection
16 Flight Acceptance Test Complete
17 Deep Space Network Compatibility Test Support
18 Operational Support Equipment Operation Verified
19 Entry Science Package - ETM
20 Entry Science Package - PTM
21 Entry Science Package - First Flight Articles
22 Surface Laboratory System - First Flight Articles
23 Fabrication Start

Fig. 31. Master Schedule.

This sequence allows the incorporation of any changes generated from subsystem level qualification testing into the system qualification model.

The Proof Test Model will be qualified before final assembly of the Flight Capsules. This will ensure that the configuration of the Flight Articles will be exactly that of the Proof Test Model.

Finally, in recognition of the fact that the best schedule needs some insurance to guarantee the end objective and to provide for management schedule options, we have planned for a three-month schedule reserve in the master schedule in the time between the delivery of the fourth flight article to Kennedy Space Center and the launch date.

Key milestones at all levels of the Work Breakdown Structure will be designated to recognize critical program events and thereby provide top management visibility and control. These milestones will be identified and recommended by Martin Marietta and approved by NASA. Specific responsibility for these milestones will be designated, and the schedule dates for their completion will not be changed without prior approval by NASA. By judicious selection of these events, the schedule status of the program can be assessed without the need to analyze a large mass of data. They will also promote a common understanding of the critical program schedule areas.

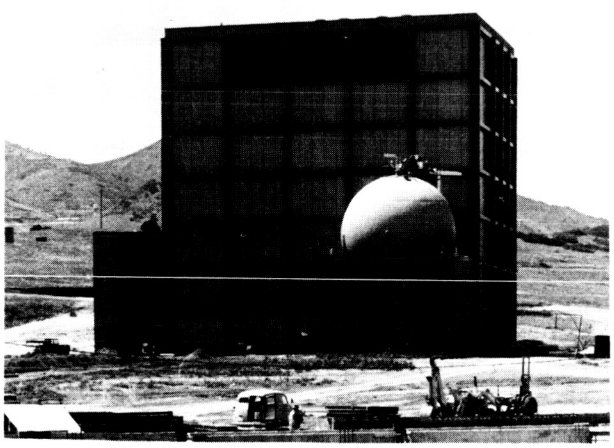


Fig. 32. The Existing Space Simulation Laboratory Is a 29- by 40-Foot Thermal Vacuum Chamber Capable of Testing the Flight Capsule. An Intermediate Chamber Is Being Added for Tests of Subsystems Comparable to Those in Voyager. Provisions Are Being Developed for a 20-Foot Solar Simulator for Use in the Large Vacuum Chamber.

With the sequencing of the key activities described above, the provision for schedule reserve and the designation of controlled milestones, we have developed what we believe to be a realistic schedule and one that we are confident will achieve the launch date in 1973.

LONG LEADS

During the Phase B study, certain activities have been identified as requiring early attention in order to achieve key schedule events. We have designated these items as having exceptionally long lead requirements and have listed below the most significant:

1) Terminal Descent and Landing Radar and Altitude Marking Radar--Early flight testing of engineering models in Phase D requires breadboarding, detailed design, and the start of procurement and fabrication during Phase C.

2) Sterilizable Battery--Sterilization effects, cell separation material, case material, plate materials, limited recharge capability, and performance degradation require development testing in Phase C.

3) Deorbit and Terminal Descent and Landing Engines--Development of a monopropellant engine with 1400 pounds thrust and a 12:1 throttle ratio. Maximum thrust of existing engines is 340 pounds. Development testing must start in Phase C.

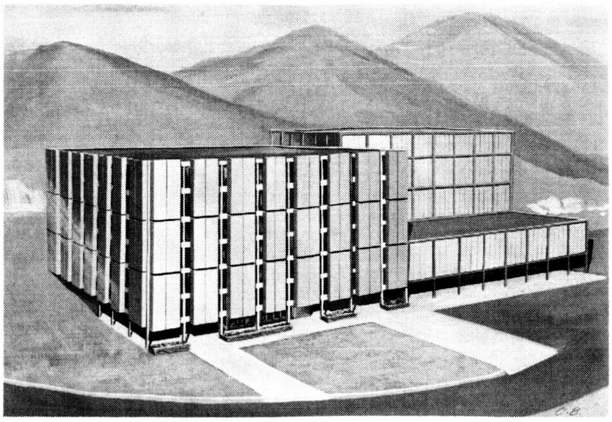


Fig. 33. The Spacecraft Assembly and Test Building Shown in the Artist's Concept Is Presently Being Designed for Construction Near the Space Simulation Laboratory.

4) Thermal Control Subsystem--Full scale model required in Phase C to provide empirical data for thermal environments.

5) Computer Software--New test programs must be developed for subsystem and system tests. Verified programs must be available early in Phase D for subsystem tests.

6) Deceleration Parachute--Full scale aerodynamic tests are required in Phase C so that the parachute design is verified before the Phase D detailed design and qualification of the decelerator subsystem.

7) Instrument Development of Hygrometer--The expected Martian atmosphere will require a highly sensitive and stable hygrometer. The existing aluminum oxide instruments will require further development to ensure proper sensor operation within tolerable accuracy limits. This development must start in Phase C if this instrument is to be available for the Entry Science Package.

8) Tape Recorders--Development and testing of a sterilizable magnetic tape must start in Phase C so that the tape recorder hardware can meet Phase D requirements.

OPERATIONS PLANS

In forming the program organization, we considered it essential that the Phase B organization, personnel, and concepts be maintained through all phases of the program with only minor modifications to accommodate the additional activities to be conducted in Phases C and D. Basic concepts included in this approach are:

A Program Director, reporting directly to the Vice President, Denver Division, with complete authority to commit the Corporation on all program matters and to take the necessary action to muster resources of the Corporation in support of the program

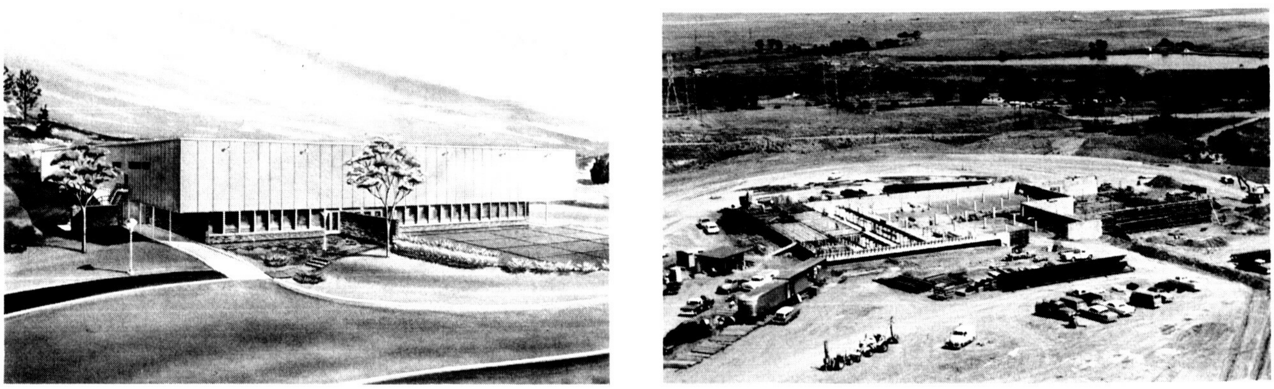


Fig. 34. Artist's Concept (Left) and Construction Photo (Right) of a New Electronics Manufacturing Facility Adjacent to Our Other Space Facilities.

Management and Technical Review Councils at the Vice Presidential level to ensure top management attention and support from inception through completion of the program

Business management and control activities -- Contracts, Finance, Project Control, Administration, Configuration Control, Data Management, and Facilities -- centralized under a Program Director of Management Operations

Establishment of open lines of communication with NASA during all post-Phase B activities, including plans for a NASA office at the Denver Division to ensure rapid and accurate response to NASA direction

Focus of attention on critical program areas by establishing 1) a Capsule parts, materials and processes control board, 2) a sterilization control committee, 3) an integrated test board, 4) a data review board, and 5) a configuration control board

Establishment in Phase D of a Capsule Team that will identify a team leader with responsibility for the technical integrity of a capsule system from initial assembly and checkout through launch operations.

Technical Control

As in the case of program organization, it was considered essential in Phase B to establish and implement the technical management techniques required for the successful completion of Phases C and D. To this end, the following techniques were identified and implemented (to the extent practicable) during Phase B.

The early identification and understanding of technical risks, critical modes, and problem areas

An understanding of the science objectives and their influence on the Capsule Bus System

Early establishment of the preferred configuration backed up by documented analyses and trade studies

The preliminary mockup and breadboarding of all critical subsystems

Formal and fully documented design reviews of our own and subcontractor technical efforts

The assignment of a Product Integrity Engineer to each critical component, assembly, and subsystem to provide single responsibility for technical performance

Use of a system evaluation model, to provide mission success probability, capsule performance, cost effectiveness, and sterilization control data.

Configuration Management

The configuration management system for the Voyager Capsule program will require all of the configuration tools normally used for configuration identification, definition, compliance, change control, and status accounting. These tools will be supplemented by a comprehensive updating of the existing configuration management system. This updating will provide by Phase C of the Voyager Program the near real time reporting and management required to support the planetary Quarantine and reliability programs. This will include part contamination reporting and sterilization probabilistic data furnished by the existing sterilization model (Fig. 35) plus detailed traceability data for reliability and sterilization.

A definitive interface program is proposed for the integration of the capsule system to provide compatible systems on schedule and within cost.

The existing Martin Marietta data management system has been evaluated, and studies are currently in process to develop the additional capability required to

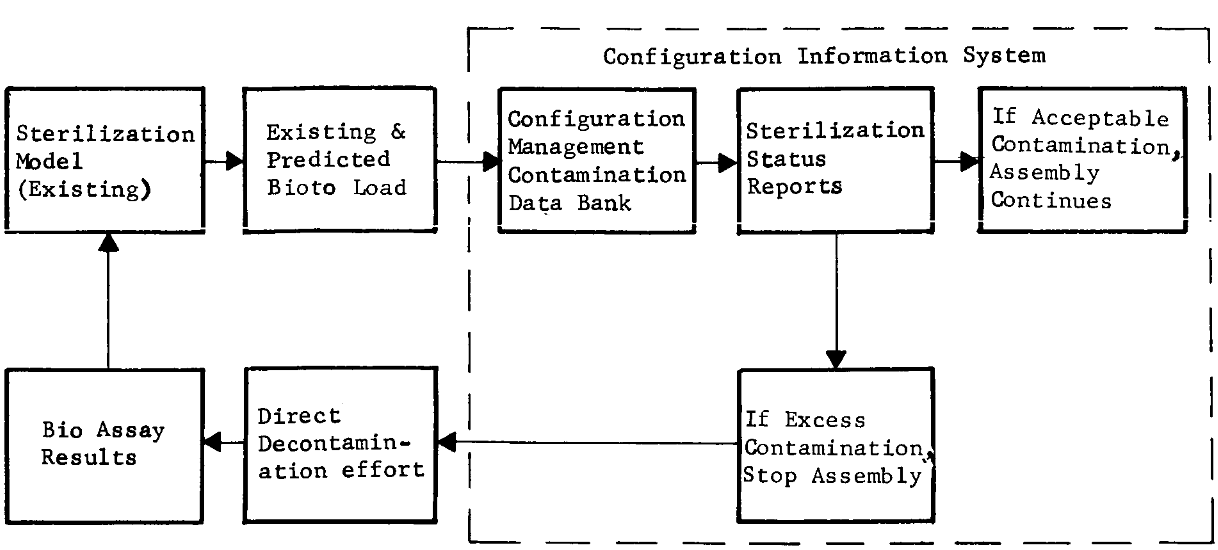


Fig. 35. Sterilization/Configuration Management.

handle and report the large volume of data that will be generated in accomplishing the Voyager program. This includes a review of data identification and review methods, data scheduling and status, improved data production methods, data storage and retrieval systems, and real time reporting methods. The emphasis is on reducing the amount of data to the minimum required while improving the reporting cycle.

Subcontract Management

The work conducted by major subcontractors must be integrated with Martin Marietta's efforts. Thus, it is essential that the subcontractors technical direction and project control be managed and monitored by Martin Marietta with the same techniques we employ for our efforts. To meet this requirement, our subcontract management techniques encompass the following concepts:

Identification of "major" subcontracts (such as telecommunications by RCA) and "critical" procurements, such as development of a monopropellant engine. The fundamental considerations are dollar magnitude and technical complexity

Martin Marietta management teams in residence with the subcontractors for early problem identification, rapid response, and assurance of technical solution. Such a team, for example, is assigned the Rocket Research Corporation in connection with development of an attitude control system for one of our programs. On Voyager, such teams would be employed in Phases C and D

Closed-loop communication between Martin Marietta and subcontractors, including a work-direction system identical to that used within our system

Technical management of subcontractor efforts assigned to a specific Martin Marietta subsystem engineer (product integrity engineer)

Participation by subcontractor representatives in such activities as the Capsule Piece Parts, Materials, and Processes Board and the Sterilization Control Committee.

Project Control

The Voyager project control plan is based on the Martin Marietta Integrated Management System as shown in Fig. 36. Significant elements of this system are:

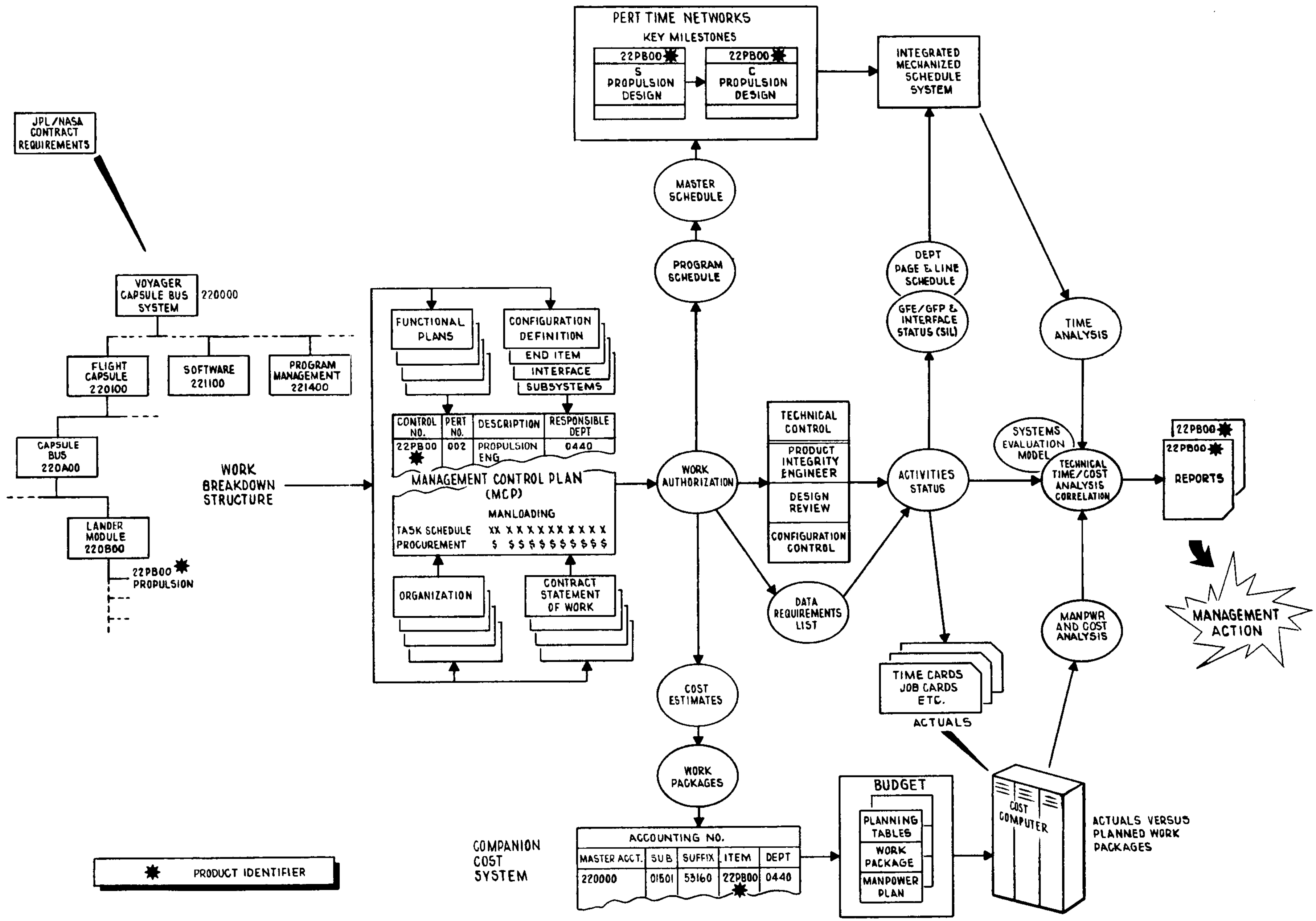


Fig. 36. Martin Marietta Integrated Management System.

A Work Breakdown Structure that divides program requirements into manageable units so controls can be exercised at all levels

Controls based on the Work Breakdown Structure such as Management Control Plans, Design Reviews, PERT Networks, schedules, budgets, and reports to provide integrated control of technical, time, and cost performance

A "Product Identifier," which is a code number assigned to elements of the Work Breakdown Structure, used as a common identification number for control elements such as schedules, cost accounts, specifications, drawings, and processes

A schedule interface log that identifies and shows the status of all exchanges required between principals

Work authorized only by an Operations Directive, which provides clear and complete direction to all personnel levels

A configuration definition and management system able to provide daily configuration data

A Corrective Action Control Committee that assembles all data pertaining to piece-part or system anomalies and provides a follow-up until the item is resolved. This provides a quality status of the hardware.

Organization

Management of the Phase B contract and related activities has been conducted by the Voyager Program organization shown in Fig. 37. The organizational relationship of the Voyager program, Denver Division, and corporate management is shown in Fig. 38.

TECHNICAL REVIEW BOARD		
Name	Title or Position	Organization
Dr. A. C. Hall, Chairman	VP, Engineering	Martin Marietta Corp, Aerospace Group
Dr. R. M. Ashby	VP, Technology	NAA, Autonetics Division
D. Shore	Chief Engineer	RCA, Defense Electronics Division
C. B. Sung	VP, Research & Engineering	The Bendix Corp, Research Laboratories Div.

PROGRAM SCIENTIST

W. W. Bender

- Analyze the primary program goals to ensure compliance with the objectives of the mission experiments
- Direct determination of requirements generated by Voyager science objectives
- Assist in resolving constraints imposed by other subsystems on scientific mission
- Maintain liaison with scientific community

STERILIZATION ASSURANCE

A. A. Rothstein

- Direct the program sterilization effort
- Define sterilization requirements
- Develop sterilization methods, processes, and the sterilization plan
- Chair the sterilization control committee
- Direct independently funded sterilization activities

RELIABILITY ASSURANCE

Dr. J. W. Carter

- Direct the program reliability effort
- Develop the reliability program plan
- Maintain liaison & conduct technical exchange with subcontractor & JPL/NASA reliability personnel
- Chair capsule parts, materials & processes bo
- Provide for a corrective action and control center for all failures and discrepancies

Name	SCIENTIFIC CONSULTANTS Specialty	Organization
Dr. V. W. Greene	Sterilization	Univ. of Minnesota
~~Dr. G. Silverman~~	~~Sterilization~~	~~MIT~~
	Voyager Insulation Studies Clean Room Techniques & Certification	A. D. Little Co. Royco Instruments
R. A. Yereance	Sterilization Effects on Soldered Connections and Outgassing	Battelle Memorial Institute
Dr. G. V. Levin	Biological Experiments in Space	Biospherics Research, Inc.
Dr. H. G. Heinrich	Use of Parachutes	Univ. of Minnesota
Prof. L. Jones Mr. E. Schaefer	Martian Atmospheric Measurements	Univ. of Michigan, High Altitude Engineering Lab
Dr. C. Sagan	Mars Surface Property & Extra-terrestial Life Search	Harvard U., Smithsonian Astrophysical Observatory
Dr. Gordon Hall Dr. C. Treanor	Technology Base for a Mars Atmosphere Entry Experiment	Cornell - Aeronautical Laboratory, Inc.
Dr. G. Patterson Dr. J. deLeeuw Dr. J. French	Technology Base for a Mars Atmosphere Entry Experiment	Univ. of Toronto, Institute for Aerospace Studies
M. Winter	Configuration Development	Syscon, Inc.
Dr. G. P. Kuiper	Planetary Astronomy	Univ. of Arizona
Dr. T. Owens	Biological Control Programs	Melpar, Inc.

MANAGEMENT OPERATIONS

C. N. Castle

- Direct the program business management effort
- Oversee development & operation of all program implementation, monitoring & control systems and plans
- Ensure compliance with contract requirements on established schedules & within funds provided
- Provide management services required to successfully meet objectives of program

- Dir
- Res OSE app
- Res Sys wit
- Fin tio
- Tec cog
- Act

Reports to Program Director

TECHNICAL DIRECTOR
C. deMoraes

SYSTEMS ENGINEERING
J. D. Goodlette

- Provide system design, test & operations requirements
- Direct system level analysis & trade studies
- Define systems interface (Capsule Bus, Surface Laboratory, & Entry Science Package)
- Provide technical direction to Hughes in the interchange of technology
- Act for the Technical Director in his absence

STRUCTURES & MECHANICS
R. W. Seiferth

- Establish design criteria & preliminary design for ground and flight structures and mechanisms

OSE
C. W. Case

- Determine requirements, and establish design criteria and preliminary design for OSE, ASHE, and System Test Complex

SCIENCE SUBSYSTEMS
Dr. J. W. Cox

- Establish design criteria & preliminary design of the Entry Science Subsystem for the Entry Science Package
- Provide technical direction to Bendix for establishing design criteria and preliminary design of the landed Science Subsystem and associated OSE for the Surface Laboratory

ENGINEERING OPERATIONS
J. F. Dwyer

- Provide support via pieceparts control, logistics, procedures, & environmental lab facility requirements

ENGINEERING RELIABILITY
F. Condos

- Establish Environmental Stress test levels
- Provide failure mode, effects, and critically analyses
- Establish reliability allocation for subsystems and components
- Provide and maintain current predictions and estimates for problem identification

SYSTEMS TEST & LAUNCH OPERATIONS
L. Edelstein

- Delineate all tests & operations necessary to prove design and identify system problems and weaknesses
- Develop integrated test and launch operations program plan

MISSION OPERATIONS
D. B. Sparks

- Conduct space flight operations studies
- Provide operational input to the preliminary design effort
- Develop the mission operations plan

Fig. 37. Continued

PLANS & ADMINISTRATION

J. Schlesselman

- Develop & Implement the Organization Plan
- Define and Develop Management Systems
- Provide and Monitor Policies & Procedures
- Provide Computer Support

FACILITIES

W. Roberts

- Analyze & identify program facility requirements
- Develop facility plan
- Ensure availability of facilities in line with program schedules

PROPULSION & THERMAL

C. D. Brown

- Establish design criteria & preliminary design for propulsion & thermal control

GUIDANCE & CONTROL

H. Von Struve

- Establish design criteria & preliminary design for guidance, control, command, and sequencing
- Provide technical direction to NAA

TELECOMM & POWER

W. Mielziner

- Establish design cri & preliminary design telemetry, communica and power
- Provide technical di tion to RCA

SYSTEM DESIGN & INTEGRATION

R. S. Wiltshire

- Establish system design characteristics
- Finalize guidelines for total system and subsystem requirements
- Define inter-system integration of Voyager systems
- Perform system trade studies
- Provide for system and interface compatibility design reviews
- Act for Systems Engineering Manager in his absence

SYSTEM EVALUATION & MODELING

R. Cary

- Develop and implement analytic tools and methods to evaluate critical system operation data

MISSION ANALYS

W. J. Pragluski

- Define aerodynamic configuration and characteristics
- Develop and analyz flight profile, sy dynamics, and syst performance

REPORTS TO DIVISION VICE PRESIDENT

VOYAGER PROGRAM

A. J. Kullas
Program Director

TECHNICAL REVIEW BOARD

Dr. A. C. Hall (Chairman)

MANAGEMENT COUNCIL

J. D. Rauth (Chairman)

Name	Ti
J. D. Rauth	VP &
B. Kreuzer	VP &
W. F. Sauers	Exec
J. L. Helms	VP &
Dr. F. P. Adler	VP &

QUALITY ASSURANCE & SAFETY

E. C. Daniel

- Direct the program quality and safety effort
- Provide quality planning and support for the design and development effort
- Develop procedures and controls to verify the quality of materials, processes, and products
- Ensure implementation of supplier quality and safety controls
- Provide a failure reporting system
- Develop quality and safety program plans

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ard

RCA
Astro-Electronics Div.

M. S. Cohen

- Preliminary design & supporting OSE for RF communications, imaging equipment, & tape data storage

BENDIX
Aerospace Systems Div.

R. D. Ormsby

- Preliminary design, supporting OSE, for landed science subsystem of the general assistance on SLS

TECHNICAL DIRECTOR

C. A. deMoraes

ect the program engineering effort
ponsible for design of qualified hardware, , MDE, & finalization of preferred design roach
ponsible for integration of Capsule Bus tem with SLS, & definition of interfaces h other Voyager systems
alize integrated test plan, launch operans plan, & mission operations plan
hnically direct all subcontractors through nizant engineering managers (PIE's)
for program director in his absence

TECHNICAL STAFF

R. MESNARD

FABRICATION & ASSEMBLY

N. L. James

- Direct the program manufacturing effort
- Define advanced manufacturing technology developments for processes & materials, as well as special manufacturing facility requirements
- Analyze and provide for the effect of sterilization & reliability requirements on manufacturing operations
- Maintain build schedules
- Fabricate mockups & breadboards
- Develop manufacturing plan for the fabrication and assembly of all prototype and flight hardware

PROC

F.

- Direct progra contract effo
- Develop and f & subcontract
- Definitize &
- Control & adm
- Establish and major subcon

Reports to Program Director

MANAGEMENT OPERATIONS
C. N. Castle

CONTRACTS ADMINISTRATION
L. O. Baldassari

- Negotiate & administer contracts
- Submit & negotiate changes to contract statement of work
- Issue work authorization directives
- Control contractual correspondence
- Status contract task completions

CONFIGURATION & DATA MANAGEMENT
R. L. Jones

- Develop & implement the data management and configuration management plans
- Prepare, negotiate, and maintain product & interface specifications
- Establish & operate a configuration management system
- Provide for a data review board and configuration control board

PROJECT CONTROL
S. B. Bertuzzi

- Develop project control and implementation plans
- Prepare & maintain program schedules, work breakdown structure, and management networks
- Administer & control program budgets & cost performance systems
- Report program status

ESTIMATING & PRICING
M. L. Cramer

- Estimate program costs
- Provide financial information & cost analyses
- Assist in contract negotiations

MANAGEMENT COUNCIL

le or Position	Organization
Gen. Manager	Martin Marietta Corp, Aerospace Group, Denver Division
Gen. Manager	RCA, Astro-Electronics Division
, Vice President	NAA, Autonetics Division
Group Manager	The Bendix Corp, Aerospace Systems Division
Asst Group Exec.	Hughes Aircraft Co., Aerospace Group

test data
LS and for

NAA
Autonetics Div.

R. R. Mueller

- Preliminary design, supporting OSE, & test data for guidance sensor subsystem

HUGHES
Space Systems Div.

Dr. R. Cheng

- Provide related surveyor technology experience in terminal descent, leg landing gear, OSE design, & test planning support

REMENT

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procurement & sub-

alize overall procurement
plan
gotiate subcontracts
ister major subcontracts
anage resident teams at
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Fig. 37. Voyager Program, Phase B Organization.

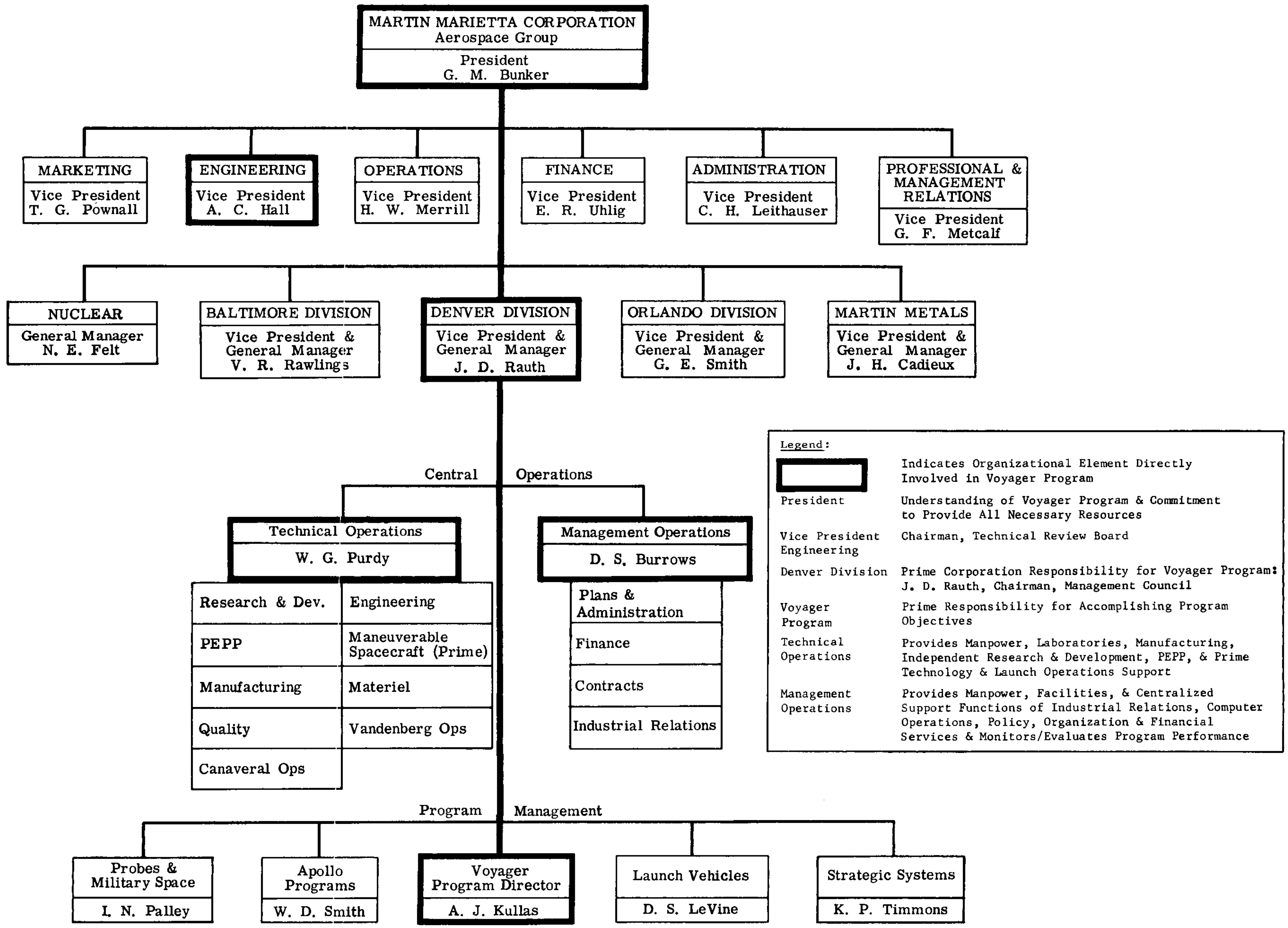

Fig. 38. Martin Marietta Corporation Aerospace Group.